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- *Journal of Exercise Therapy and Rehabilitation (JETR) is published three times yearly, in April, August and December.*
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İçindekiler / *Contents*

ORIGINAL ARTICLE

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ORIGINAL ARTICLE

Biopsychosocial exercise model via telerehabilitation in individuals with rheumatic disease

Romatizmal hastalığı olan bireylerde telerehabilitasyon yoluyla biyopsikososyal egzersiz modeli

Zeynep İrem BULUT[1], Nur Banu KARACA[2], Yavuz YAKUT[3], Sevim ÖKSÜZ[4], Sedat KİRAZ[5], Edibe ÜNAL[2]

Abstract

Purpose: The aim of this study was to investigate the effects of the biopsychosocial exercise model applied via telerehabilitation on individuals with rheumatism during the COVID-19 epidemic.
Methods: Individuals with rheumatic diseases received telerehabilitation 3 times a week for 24 weeks via a social messaging program intervention sessions formed from 10 minutes of dance therapy-authentic movement, 40 minutes of exercises, and 10 minutes of dance therapy. This exercise content was based on the biopsychosocial model, named as Cognitive Exercise Therapy Approach (BETY) which was a method that individuals had already practiced before the pandemic. The Health Assessment Questionnaire (HAQ) was used to assess the level of disability, the Hospital Anxiety and Depression Scale (HADS) was used to assess mood involvement, and the BETY Biopsychosocial Questionnaire (BETY-BQ) was used to assess biopsychosocial involvement level. Evaluations were made at the beginning of the study and repeated at the 12th and 24th weeks.
Results: A total of 28 individuals with rheumatic diseases were included in the study and their mean age was 56.50 ± 5.51 years. There was a significant difference between the first and second assessment of HAQ (p= 0.031), between the first and second assessment of BETY-BQ (p= 0.004) and between the third and first assessment (p= 0.015).
Conclusion: The application of BETY with telerehabilitation helped individuals maintain the level of recovery they had previously achieved in terms of disability, mood level and biopsychosocial. These results indicate that individuals with rheumatic diseases can continue the remote application via telerehabilitation to support their health after experiencing biopsychosocial exercise approaches face-to-face.
Keywords: Telerehabilitation, Biopsychosocial model, Rheumatology, Exercise.

Öz

Amaç: *Bu çalışmanın amacı, COVID-19 salgını sırasında romatizmalı bireylerde telerehabilitasyon yoluyla uygulanan biyopsikososyal egzersiz modelinin etkilerini araştırmaktı.*
Yöntem: *Romatizmal hastalığı olan bireylere sosyal mesajlaşma programı aracılığıyla 24 hafta boyunca haftada 3 seans telerehabilitasyon uygulandı. Müdahale seansları 10 dakikalık dans terapisi-otantik hareket, 40 dakikalık egzersiz ve 10 dakikalık dans terapisinden oluşuyordu. Bu egzersiz içeriği, çalışmada kullanılan Bilişsel Egzersiz Terapi Yaklaşımı (BETY) olarak adlandırılan ve hastaların pandemiden önce de uyguladığı bir yöntem olan biyopsikososyal modele dayanıyordu. Yetiyitimi düzeyini değerlendirmek için Sağlık Değerlendirme Anketi (HAQ), duygudurum etkilenimini değerlendirmek için Hastane Anksiyete ve Depresyon Ölçeği (HADS) ve biyopsikososyal düzey etkilenimini değerlendirmek için BETY Biyopsikososyal Anketi (BETY-BQ) kullanıldı. Değerlendirmeler çalışmanın başında yapıldı ve 12. ve 24. haftalarda tekrarlandı.*
Bulgular: *Çalışmaya toplamda 28 romatizmal hastalığı olan birey dahil edildi ve yaş ortalamaları 56,50 ± 5,51 yıldı. HAQ'nun birinci ve ikinci değerlendirmesi arasında artan (p= 0,031), BETY-BQ'nun birinci ve ikinci değerlendirmesi arasında azalan (p= 0,004) ve üçüncü ve birinci değerlendirmesi arasında artan (p= 0,015) anlamlı fark bulundu.*
Sonuç: *BETY'nin telerehabilitasyon ile uygulanması yetiyitimi, duygudurum düzeyi ve biyopsikososyal açıdan bireylerin daha önce kazanmış oldukları iyileşme düzeyinin korunmasına yardımcı oldu. Bu sonuçlar, biyopsikososyal egzersiz yaklaşımları yüzyüze deneyimlendikten sonra romatizmal hastalığı olan bireyler sağlıklarını desteklemek için telerehabilitasyon yoluyla uzaktan uygulamayı sürdürebileceklerini göstermektedir.*
Anahtar kelimeler: *Telerehabilitasyon, Biyopsikososyal model, Romatoloji, Egzersiz.*

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INTRODUCTION

The COVID-19 pandemic has placed significant strain on health systems worldwide, limiting access to healthcare services for many individuals with chronic diseases. During this period, both the direct and indirect consequences of service disruptions have adversely affected the mental health (e.g., depression, anxiety, stress), physical function, and biomedical status of individuals with rheumatic diseases.[1-3] Reduced physical activity has led to increased disease activity, worsening symptoms (e.g., pain), and a heightened cardiovascular risk profile, while also contributing to declines in mental health, physical capacity, functionality, and overall quality of life.[3-4] Furthermore, individuals with rheumatic diseases have experienced greater social isolation compared to healthy individuals during this time.[5]

With the onset of the pandemic, physical activity and exercise have gained increased significance due to their numerous health benefits. The importance of participating in structured exercise programs has been emphasized to mitigate the negative effects of the pandemic on individuals with rheumatic diseases, particularly in reducing the risk of fatigue, sarcopenia, and depression during quarantine.[6] During this period, clinicians and other healthcare professionals played a crucial role in promoting physical activity levels.[3] As movement specialists, physiotherapists, in particular, have a key responsibility in maintaining and even enhancing individuals' overall health status.

Telerehabilitation services were recommended as the primary option for individuals receiving treatment at home, primarily due to their role in reducing the risk of transmission.[6] Before the COVID-19 pandemic, several significant barriers hindered the widespread adoption of telerehabilitation, including implementation complexity, cost, lack of urgency for change, resistance to new methods, insufficient participation in planning, challenges in conducting physical assessments, and inadequate information and communication technology infrastructure.[7] However, following the pandemic, its popularity increased due to the necessity of social distancing and the difficulties in accessing in-person treatment. The European Alliance of Associations for Rheumatology (EULAR) has advocated for the integration of digital health services into treatment protocols, emphasizing their role in supporting self-management and empowering individuals to take a more active role in their healthcare.[8]

A systematic review evaluating the effectiveness of real-time telerehabilitation concluded that it may be superior to standard practice in enhancing physical function for various musculoskeletal disorders.[9] Evidence suggests that telerehabilitation effectively reduces pain intensity, pain catastrophizing, and depression levels while improving functionality and quality of life in conditions such as osteoarthritis and fibromyalgia.[10,11] Furthermore, research indicates that the primary determinant of effective recovery in telerehabilitation-based exercise programs is not the delivery method itself but rather the content and structure of the rehabilitation program.[10] EULAR has recommended the integration of telehealth into non-pharmacological interventions, including disease education, guidance on physical activity and exercise, self-management strategies, and psychological treatment for remote care in individuals with rheumatic and musculoskeletal diseases. It has been emphasized that the mode of implementation should be tailored to the individual's prior experience with treatment and the specific nature of the intervention.[12]

EULAR has recommended that healthcare professionals in rheumatology adopt a holistic approach aligned with the biopsychosocial model in disease management and conduct comprehensive assessments.[13] The Cognitive Exercise Therapy Approach (Bilişsel Egzersiz Terapi Yaklaşımı-BETY) is an exercise-based intervention rooted in the biopsychosocial model, specifically developed for individuals with rheumatic diseases, with its effectiveness demonstrated in clinical practice.[14-16] In a study involving individuals with systemic sclerosis, one group participated in BETY training three days a week for three months via telerehabilitation after completing initial BETY stages through face-to-face sessions, while the control group followed a home exercise program. The findings revealed that individuals who engaged in BETY telerehabilitation experienced

significant improvements in functionality, muscle strength, vascularization, inflammation, and overall biopsychosocial status.[17]

In this context, expanding the application of telerehabilitation for individuals with rheumatic diseases who lack access to treatment is crucial for sustaining the therapeutic benefits previously achieved through biopsychosocial exercise models, particularly during periods of restricted healthcare access, such as pandemics. However, no studies in the existing literature have investigated the implementation of a biopsychosocial exercise model via telerehabilitation for various rheumatic diseases. Therefore, this study aimed to evaluate the effectiveness of the BETY exercise model delivered through telerehabilitation in the disease management process of individuals with rheumatic diseases during the pandemic, as well as its long-term sustainability and the maintenance of previously attained treatment outcomes

METHODS

The Declaration of Helsinki's guiding principles were followed when conducting this study. Approval was granted by the Ethics Committee of Hacettepe University (GO-18/1182). Written and verbal informed consent was obtained from the individuals. It was announced that personal information would be protected within the scope of the privacy policy and would not be shared with third parties.

Participants

Individuals with rheumatic diseases who were members of an exercise group at Hacettepe University Faculty of Physical Therapy and Rehabilitation before the pandemic were included to this study. This exercise group gathered to accomplish a biopsychosocial exercise program for 40 minutes, three sessions per week after receiving their diagnosis from the Hacettepe University Rheumatology Department. When face-to-face sessions were discontinued due to pandemic, 51 out of 91 volunteer individuals agreed to join the online exercise group and continue their treatment via telerehabilitation using WhatsApp (Meta Platforms Inc, California). The telerehabilitation exercise sessions began just one week after the onset of the pandemic. However, individuals who had difficulty reading and writing messages or following the exercises in real time were excluded from the study. As a result, 28 individuals consistently attended the exercise sessions and were included in this study.

The sample size of the study was calculated as 34 using the G* Power 3.0 program, assuming effect size (dz) = 0.5, $\alpha = 0.05$, $\beta = 0.20$ and 80% power values according to the 'difference between two dependent means -matched pairs' test to calculate the effect size value.

Telerehabilitation

Telerehabilitation was implemented for the group as 3 weekly sessions over a 24-week period using a social messaging platform. Each intervention sessions consisted of three main components: 10 minutes of dance therapy-authentic movement (including the 3 minutes of walking with small and large steps, followed by dancing to two songs), 40 minutes of exercises (pain management and cognitive restructuring strategy during exercise), and 10 minutes of dance therapy-dramatization (positive thought awareness and positive goal setting maneuver). This exercise program was based on the Cognitive Exercise Therapy Approach (BETY), a biopsychosocial model that individuals were already familiar with from pre-pandemic in-person sessions. which was a method that individuals already practiced before.

The exercises were delivered via text messages on the social messaging platform, without the use of video or voice communication. Instructions were given by the physiotherapist during the sessions, and participants performed the exercises while simultaneously providing feedback through text. For the first 12 sessions, a physiotherapist supervised the exercises. After this period, participants continued the program independently. In previous face-to-face training, some individuals had voluntarily taken on leadership roles within the exercise group. The same approach was adopted for telerehabilitation, with 12 individuals volunteering as session leaders These individuals alternated in leading the sessions, using text-based instructions similar to those provided by the physiotherapist during the initial 12 weeks.

BETY is an exercise approach grounded in the biopsychosocial model, designed to treat the individuals with rheumatic diseases holistically.

It integrates components that promote mind-body connection, pain management, mood regulation and education on disease-related topics including sexual health. BETY ensures mind-body connection through function-oriented body stabilization exercises incorporating core stabilization movements combined with extremity exercises. It employs positive thinking as a precursor to movement and utilizes distraction strategies for pain management. Mood regulation and pain distraction are further supported through positive thinking, authentic movement, and dance therapy. Additionally, BETY aims to inform the individuals about their disease mechanisms and progression, enhance body awareness empower individuals by fostering autonomy in disease management, and provide social support through group-based exercise sessionss.[14-17]

Outcomes

Sociodemographic information of the individuals such as age, height, body weight, body mass index, disease duration, and diagnoses was recorded. Evaluations were made at the beginning of the study and the 12th and 24th weeks with the Health Assessment Questionnaire (HAQ), Hospital Anxiety and Depression Scale (HADS), and BETY Biopsychosocial Questionnaire (BETY-BQ).

BETY-BQ was developed by feedback received from individuals with rheumatic diseases who had attended BETY sessions over many years. It is an assessment tool that evaluates the biopsychosocial involvement; pain, function, sexual behavior, and social and psychological aspects. Scoring of the questionnaire was made using the 5-point Likert system. Each question is scored as "0 = No never, 1 = Yes rarely, 2 = Yes sometimes, 3 = Yes often 4 = Yes always". A high score indicates a low biopsychosocial status.[16] Validity, reliability, and responsiveness of the questionnaire were shown in fibromyalgia, psoriatic arthritis, ankylosing spondylitis, primary Sjögren's syndrome, systemic lupus erythematosus and osteoarthritis.[19-24]

HAQ, which can be used in the evaluation of all rheumatic diseases, includes twenty questions and 8 subtitles including dressing, sitting, eating, walking, hygiene, reaching out, comprehending, and daily life activities. Each answer is rated between 0 and 3 points ("0 = No difficulty, 1 = Somewhat difficult, 2 = Very difficult, and 3 = I can never do"). Higher scores indicate lower functionality.[25] HAQ scores greater than one were regarded as proof of a disability.[26]

The purpose of the HADS was to show the depression and anxiety levels that had occurred because of the diseases. It is a 14-item scale that consisted of sub-scales; Anxiety (HADS-A) and Depression (HADS-D). The answer to each question is scored between 0-3 using the four-point Likert scale, and both sub-parameters can take a value between 0 and 21. The anxiety subscale has a cut-off score of 10/11, whereas the depression subscale has a cut-off score of 7/8. Scores beyond this threshold are associated with an increased risk of anxiety and.[27,28]

Statistical analysis

Statistical analysis was performed using SPSS software version 23 (SPSS Inc., Armonk, New York, USA). Data were expressed as mean (standard deviation) and minimum-maximum values. Wilcoxon Signed Ranks Test was used for investigating the difference between questionnaire results before and after telerehabilitation. The statistical significance level was considered as $p<0.05$.

RESULTS

Demographic characteristics of participants are given in Table 1. The majority of participants were individuals who were diagnosed with fibromyalgia (28.6%) and rheumatoid arthritis (25%).

The mean scores of questionnaires that were applied at the beginning, in the middle (12th week), and at the end (24th week) were given in Table 2. It was determined that all scores of questionnaires decreased at the second evaluation (12th week) and increased at the third evaluation (24th week) except HAQ. The questionnaires' score change in all evaluations is shown in Figure 1.

The statistical analysis of alteration in mean scores of questionnaires in assessments is shown in Table 3. A significant increasing difference was found between the 1st and 2nd assessment of HAQ, a decreasing difference between the 1st and 2nd assessment of BETY-BQ, and an increasing difference between the 1st and 3rd assessment of BETY-BQ.

Table 1. Demographic characteristics of participants (N=28).

	X±SD
Age (year)	56.5±5.5
Body Mass Index (kg/m^2)	25.6±3.1
Disease duration (year)	12.5±1.2
	n (%)
Rheumatic diagnosis	
Fibromyalgia	8 (28.6)
Rheumatoid arthritis	7 (25)
Ankylosing spondylitis	5 (17.9)
Osteoarthritis	2 (7.1)
Systemic lupus erythematosus	2 (7.1)
Polymyalgia rheumatica	2 (7.1)
Sjogren's syndrome	1 (3.6)
Vasculitis	1 (3.6)

Table 2. Mean scores of questionnaires from assessments (N=28).

	X±SD
BETY-BQ	
First assessment	44.36±19.05
12th week	36.61±16.31
24th week (a)	44.27±17.82
Health Assessment Questionnaire	
First assessment (b)	0.55±0.40
12th week(c)	0.61±0.41
24th week (a)	0.69±0.43
HADS-Anxiety	
First assessment	7.71±4.12
12th week	7.21±4.37
24th week (a)	7.88±4.11
HADS-Depression	
First assessment	5.68±4.44
12th week	5.04±3.28
24th week (a)	5.73±3.80

BETY-BQ: Cognitive Exercise Therapy Approach- Biopsychosocial Questionnaire. HADS: Hospital Anxiety and Depression Scale.

Table 3. The statistical analysis of alteration in mean scores of questionnaires in assessments.

	p
BETY-BQ	
First assessment-12th week	0.004*
First assessment-24th week	0.864
12th week-24th week	0.015*
Health Assessment Questionnaire	
First assessment-12th week	0.031*
First assessment-24th week	0.162
12th week-24th week	0.798
HADS-Anxiety	
First assessment-12th week	0.371
First assessment-24th week	0.600
12th week-24th week	0.090
HADS-Depression	
First assessment-12th week	0.362
First assessment-24th week	0.861
12th week-24th week	0.288

* p<0.05. BETY-BQ: Cognitive Exercise Therapy Approach-Biopsychosocial Questionnaire. HADS: Hospital Anxiety and Depression Scale. HADS: Hospital Anxiety and Depression Scale.

DISCUSSION

This study investigated the effects of a biopsychosocial exercise program delivered via telerehabilitation in individuals with rheumatic diseases who had previously practiced the same model through face-to-face sessions before the pandemic. The program's impact on biopsychosocial status, functionality, anxiety, and depression was evaluated. The findings indicated changes in biopsychosocial status and functionality within this patient group during the pandemic. During the initial 12-week telerehabilitation period, which was supervised by a physiotherapist, biopsychosocial status improved, whereas functionality declined. In the subsequent 12-week period, during which the sessions were led by group members under minimal physiotherapist supervision, biopsychosocial status was negatively affected. However, considering all measured parameters, individuals-whether supervised by a physiotherapist or not- were able to maintain their mental health and functional status, keeping their scores below the cut-off values of the applied questionnaires. This suggests that, despite limited access to healthcare services during the first six months of the pandemic, participants successfully preserved their overall well-being.

In this study, individuals with rheumatic diseases who participated in biopsychosocial based group exercise sessions were able to sustain their exercise habits under pandemic conditions. A review of the literature revealed no prior studies that combined both group-based exercise session and a biopsychosocial approach for these individuals during the COVID-19 pandemic. In this regard the present study

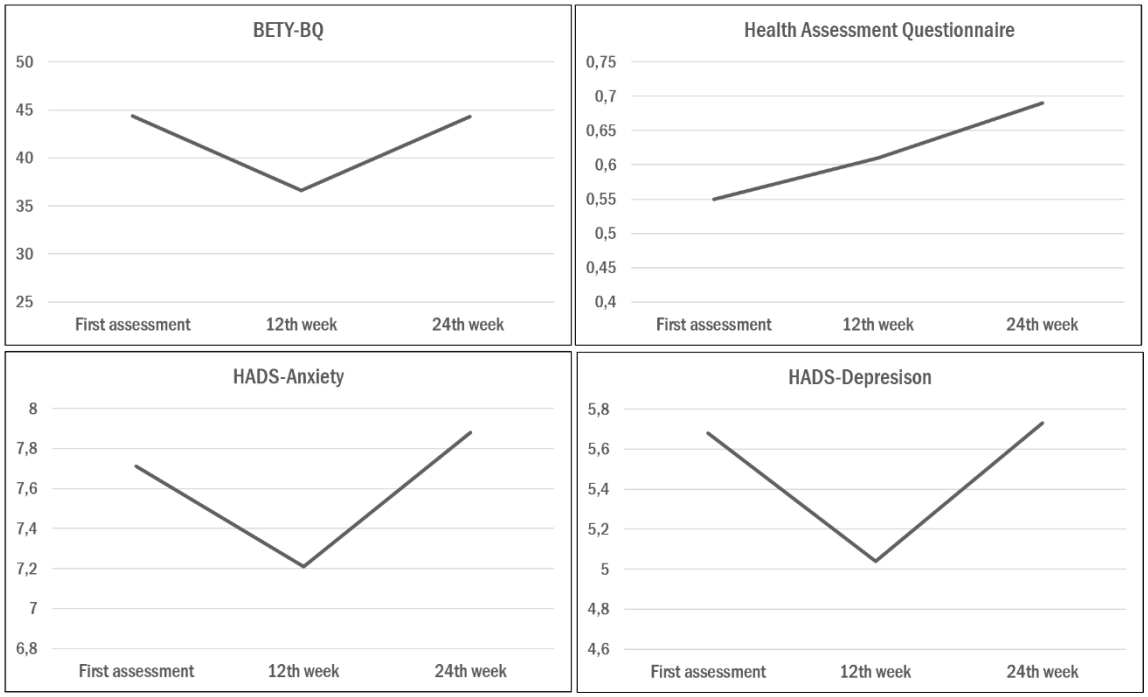

Figure 1. Change of scores of questionnaires during all assessments. BETY-BQ: Cognitive Exercise Therapy Approach-Biopsychosocial Questionnaire. HADS: Hospital Anxiety and Depression Scale.

highlights the significance of rheumatic individuals developing exercise habits as recommended by clinical guidelines to ensure the sustainability of physical activity and exercise during such periods. A study summarizing the available evidence on telerehabilitation in physical therapy reviewed systematic reviews in this field.[29] Among 53 systematic reviews, there was considerable diversity in the patient populations examined; however, only one review focused on rheumatic diseases, osteoarthritis. Although findings on telerehabilitation remain inconsistent and sometimes contradictory, it has been emphasized that higher-quality studies in this field could contribute to improved clinical outcomes both during the COVID-19 pandemic and in the future. Moreover, studies incorporating telemedicine-based interventions-such as medication management, exercise training, and cognitive, behavioral therapy-have been increasingly emphasizing holistic approaches in patient care. [30] However, given that the management of rheumatic diseases requires lifelong behavioral changes, it is evident that further research is needed to establish effective and sustainable exercise interventions for this population.

In our study a significant improvement in the biopsychosocial status of participants with various rheumatic diseases was observed during the first 12 weeks of telerehabilitation followed by a decline in the subsequent 12 weeks. In a study conducted by Çağlayan et al., the BETY-BQ was used to assess the biopsychosocial status of women with fibromyalgia. This study compared the effects of face-to-face clinical Pilates exercises performed in group and individual settings, demonstrating that BETY-BQ scores improved in both groups.[31] It was suggested that the greater improvements observed might be attributed to the need for individuals to feel a sense of supervision and support from a physiotherapist, even if they were already familiar with the training program.

In our study functional level of individuals did not change significantly, and no disability was detected in all three measurements. A recent systematic review and meta-analysis,

which included six randomized controlled trials examining the effects of internet-based rehabilitation programs on pain and physical function in individuals with knee osteoarthritis, concluded that these programs improved pain but did not significantly enhance physical function, highlighting the limited number of available studies.[32] In another study involving individuals with knee osteoarthritis, the control group was granted access to a specially designed website providing information about the disease and the importance of exercise and physical activity.[33] In contrast, the intervention group was received additional support, including a 24-week self-administered strengthening program and automated behavior change text messages aimed at promoting that promoted exercise adherence and increasing physical activity levels. The intervention group demonstrated greater improvement in overall knee pain and physical function compared to the control group.

In a study conducted by van den Berg et al., the effectiveness of two different internet-based physical activity interventions in individuals with rheumatoid arthritis were compared. One group participated in a structured physical activity program that included exercise equipment, group communication, and an individualized exercise program (strengthening, range of motion exercises, and bicycle ergometry). The other group had access to a website, providing general information about exercises and physical activity. The study found improvements in functional levels in both groups, with the most significant gains observed in the individualized exercise group.[34] The heterogeneity in study methodologies may have contributed to these differences. Additionally, these studies were not conducted during the COVID-19 pandemic. The primary distinction of our study was that it was carried out during the first six months of the pandemic, a period when rehabilitation services were largely unavailable. The ability of participants in our study to maintain their functional levels may be attributed to the exercises performed through telerehabilitation.

In our study, the anxiety and depression levels of the participants remained unchanged, with baseline values already indicating no signs of depression or anxiety at the onset of the pandemic. In a randomized controlled trial investigating the effects of an aerobic exercise-based telerehabilitation program in women with fibromyalgia during the COVID-19 quarantine period, the intervention group participated in individual exercise sessions twice a week for 15 weeks, while the control group received no additional intervention. The study results demonstrated a statistically significant improvement in both the depression and anxiety subscales of the HADS in the exercise group compared to baseline and the control group. Notably, the initial anxiety and depression levels of the individuals in that study were reported to be above the cut-off value of the scale.[35] In this study, written messages were used to deliver exercise instructions; however, these messages provided real-time explanations of a BETY session, replicating the format of in face-to-face training. This suggests that individuals were protected from the expected negative effects of social isolation and prolonged home confinement during the pandemic through this exercise. The sustainability of this effect may be attributed to the fact that the participants, who had been exercising regularly, had already developed adaptive coping mechanisms through prior engagement in the program. Notably, during the period of social isolation, which was associated with increased rates of depression and anxiety, individuals who had maintained regular face-to-face exercises in the pre-pandemic period and had achieved a certain level of physical and psychological well-being were able to preserve these benefits when given the opportunity to continue exercising with or without supervision. It is suggested that the group-based nature of BETY, even when applied via telerehabilitation, played a crucial role in supporting emotional well-being and preventing feelings of loneliness, reinforcing the importance of social support in home-based exercise interventions.

Limitations

Although a large number of individuals had participated in the face-to-face training sessions, some were unable to adapt to simultaneously reading the exercise messages and pain management instructions on WhatsApp while performing the exercises. Consequently, they were not included in this study and a control group could not be established. Furthermore, although these individuals did not participate in the telerehabilitation sessions, they could not be

considered a non-intervention control group, as they reported continuing the exercises at home based on their previous training. Another important limitation was the inability to include new participants in the exercise group. Individuals eligible for inclusion needed to have previously attended face-to-face exercise sessions and learned the method beforehand. With a pragmatic approach, our primary objective was to first evaluate the feasibility of applying the existing exercise model through telerehabilitation with individuals who had prior experience with it. Additionally, since this study aimed to assess the sustainability and effectiveness of the exercise program, and all the participants were under medical supervision, their medication use and comorbidities were not evaluated, representing another limitation. Future research should build upon these findings by conducting randomized controlled studies with a sufficiently large sample size, including individuals without prior exercise habits, to enhance the generalizability and effectiveness of this approach.

Conclusion

In this study, the six-month sustainability of BETY, a biopsychosocial exercise model initially implemented as a face-to-face group exercise program for individuals with rheumatic diseases, through telerehabilitation during the COVID-19 pandemic. Our study was unique in several aspects, including the use of a biopsychosocial exercise model in a group training format, and its application to individuals with rheumatic diseases during the pandemic. Since teaching and implementing biopsychosocial models remotely is challenging, it is recommended that these models be introduced through face-to-face training under normal circumstances. Notably, this study, which presents a novel approach not previously reported in the literature for individuals with rheumatic diseases, found that the only source enabling participants to continue exercising during the pandemic was the biopsychosocial exercise habits they had acquired through in-person, group-based training. These findings highlight the need to promote the widespread adoption of biopsychosocial exercise approaches, recognize the potential for individuals to sustain previously established exercise habits through remote care, and support this exercise model with comparative studies to further validate its effectiveness.

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Conflicts of Interest: *None*

Ethical Approval: This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Hacettepe University (GO-18/1182).

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ORIGINAL ARTICLE

Kronik bel ağrılı hastalarda uyku hijyeni ve solunum egzersizlerinin ağrı, özürlülük ve uykuya etkisi

Effects of sleep hygiene and breathing exercises on pain, disability, and sleep in patients with chronic low back pain

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Öz

Amaç: Kronik bel ağrısı (KBA) olan hastalarda kor stabilizasyon egzersizlerine eklenen uyku hijyeni eğitimi ve solunum egzersizlerinin ağrı, özürlülük, uyku parametreleri üzerindeki etkilerini araştırmayı amaçlamaktadır.
Yöntem: KBA tanısı konan bireyler, randomize olarak üç gruba ayrıldı. Birinci grup yalnızca TENS ve yüzeyel ısı uygulanan klasik fizyoterapi grubu (KFT), ikinci grup TENS, yüzeyel ısı ve kor stabilizasyon egzersizlerini içeren lumbar stabilizasyon egzersizi grubu (LSE) ve üçüncü grup TENS, yüzeyel ısı, kor lumbar stabilizasyon egzersizleri, solunum egzersizleri ve uyku hijyeni eğitimi uygulanan uyku hijyeni ve solunum egzersizleri grubudur (UHSE). Tüm gruplar, ilk aşamada 3 haftalık yüzyüze tedavi aldı. Daha sonra LSE ve UHSE grupları ilave olarak 5 hafta boyunca ev programlarına devam ettiler. Ağrı şiddeti Vizüel Ağrı Skalası ve McGill Ağrı Kısa Formu, özürlülük Oswestry Özürlülük İndeksi, uyku kalitesi Pittsburgh Uyku Kalite İndeksi ve gündüz uykululuğu Epworth Uykululuk Ölçeği ile değerlendirildi. Değerlendirmeler tedavi başlangıcında, 3. haftada (tedavi sonrası) ve 8. haftada (takip dönemi) yapıldı.
Bulgular: Başlangıç değerlerine kıyasla, tedavi sonrası ve takip döneminde gruplar arasında anlamlı farklar saptandı. LSE ve UHSE grupları, KFT grubuna göre ağrı şiddetini azaltma, özürlülük düzeyini düşürme, uyku kalitesini artırma ve gündüz uykululuğunu azaltmada daha etkili bulundu ($p<0.05$). Ancak, LSE ve UHSE grupları arasında bu parametrelerde anlamlı bir fark tespit edilmedi ($p>0.05$).
Sonuç: Bu çalışma, LSE ve UHSE gruplarının, KFT grubuna kıyasla ağrı, özürlülük ve uyku parametrelerini iyileştirmede daha etkili olduğunu gösterdi. Uyku hijyeni eğitimi ve solunum egzersizlerinin eklenmesi, yalnızca kor stabilizasyon egzersizlerine kıyasla KBA hastalarında ek bir fayda sağlamadı. Uzun vadeli etkileri değerlendirmek için daha kapsamlı çalışmalara ihtiyaç vardır.
Anahtar Kelimeler: Bel ağrısı, Kor stabilizasyon, Uyku hijyeni, Solunum egzersizleri, Uyku.

Abstract

Purpose: *This study aims to investigate the effects of adding sleep hygiene education and breathing exercises to core stabilization exercises on pain, disability, and sleep parameters in patients with chronic low back pain (CLBP).*
Methods: *Individuals diagnosed with CLBP were randomly assigned to three groups. The first group, received only TENS and superficial heat, forming the classical physiotherapy group (CPT). The second group received TENS and superficial heat combined with stabilization exercises, forming the lumbar stabilization exercise group (LSE). The third group received TENS, superficial heat, lumbar stabilization exercises, breathing exercises, and sleep hygiene education, forming the sleep hygiene and breathing exercise group (SHBE). All groups underwent a 3-week face-to-face treatment phase initially. Subsequently, the LSE and SHBE groups continued with a 5-week home exercise program. Pain intensity was assessed using the Visual Analogue Scale and the short form of the McGill Pain Questionnaire; disability with the Oswestry Disability Index; sleep quality with the Pittsburgh Sleep Quality Index, and daytime sleepiness with the Epworth Sleepiness Scale. Assessments were conducted at baseline, at 3 weeks (post-treatment), and at 8 weeks (follow-up).*
Results: *Compared to baseline, significant differences were observed between groups at post-treatment and follow-up periods. The LSE and SHBE groups were more effective than the CPT group in reducing pain intensity, decreasing disability levels, improving sleep quality, and reducing daytime sleepiness ($p<0.05$). However, no significant differences were found between the LSE and SHBE groups for these parameters ($p>0.05$).*
Conclusion: *This study demonstrates that the LSE and SHBE groups were more effective than the CPT group in improving pain, disability, and sleep parameters. However, the addition of sleep hygiene education and breathing exercises did not provide additional benefits compared to core stabilization exercises alone in patients with CLBP. More comprehensive studies are needed to evaluate long-term effects.*
Keywords: *Low back pain, Core stabilization, Sleep hygiene, Breathing exercises, Sleep.*

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GİRİŞ

Kronik bel ağrısı (KBA), özürlülüğün önde gelen nedenlerinden biridir ve kişisel, sosyal ve ekonomik yüklerle ilişkilidir.[1] Non-spesifik KBA, sonradan ya da doğuştan edinilmiş deformite, lenfödem, enfeksiyon, tümör, osteoporoz veya radikülopati gibi spesifik bir patolojiye bağlı olmadan ortaya çıkan bel ağrısı olarak tanımlanır.[1-3] Bel ağrısının ekonomik, sağlık ve toplumsal maliyetleri oldukça yüksektir. Örneğin, Amerika Birleşik Devletleri'nde bel ağrısının doğrudan ve dolaylı maliyetlerinin 624,8 milyar dolara ulaşabildiği bildirilmiştir.[4]

Genel olarak uyku bozuklukları ile ağrı yoğunluğunun artması veya ağrı toleransının azalması arasında bir ilişki bulunmaktadır. Ağrı ve uyku bozuklukları arasında çift yönlü bir etkileşim olduğu belirtilmiş; bu nedenle hem bel ağrısını hem de uyku kalitesini iyileştiren müdahaleler ideal bir yaklaşım olarak önerilmiştir.[5] Bel ağrısına sıklıkla eşlik eden uyku sorunları olan hastalarda yaygın tedavi yöntemi farmakolojik yaklaşımlar olsa da, bu tedavilerin sedasyon, uyuşukluk ve konfüzyon gibi yan etkilerinin yanı sıra benzodiazepin ve opioidlerin birlikte kullanımından kaynaklanan bağımlılık ve ölüm riski, non-farmakolojik tedavilere olan ihtiyacı artırmaktadır.[6,7]

Günümüzde klinik uygulama rehberleri, bel ağrısı tedavisinde terapötik egzersizler, psikolojik terapiler ve bazı durumlarda multidisipliner psikososyal rehabilitasyon gibi non-farmakolojik yöntemleri önermektedir.[6-8] Ancak mevcut klinik uygulamaların KBA'yı etkin bir şekilde tedavi etmede yetersiz kalmasının nedenleri arasında, hastaların biyopsikososyal çerçevede yeterince değerlendirilmemesi ve ağrıyı tetikleyen fiziksel ve bilişsel faktörlerin farklı kombinasyonlarına yönelik bütüncül yaklaşımların eksikliği yer almaktadır.[9] Bilişsel faktörler arasında korku, felaketleştirme, kaygı, depresyon, yüksek stres ve olumsuz inançlar; fiziksel faktörler arasında ise postüral bozukluklar, değişmiş vücut şeması, kas gücü yetersizliği, fasyal gerginlik ve kondisyon kaybı sayılabilir. Bu nedenle, tedavide tamamlayıcı ve bütüncül bir bakış açısı önem taşımaktadır.[9,10]

KBA hastalarında uyku bozukluğunun tahmini yaygınlığı %58,7 olarak bildirilmiştir.[11] KBA, uyku sorunlarının yanı sıra yaşam kalitesini düşüren ve ağrıya bağlı özürlülüğe yol açan bir durumdur. Kor stabilizasyon egzersizlerinin bel ağrısına bağlı özürlülüğü azaltmada etkili olduğu gösterilmiştir.[12] Benzer şekilde, solunum egzersizlerinin de bu konuda olumlu etkileri olduğu saptanmıştır.[13] Her iki yöntemin de bel ağrısına bağlı özürlülüğü azalttığı bilinmekle birlikte, birbirlerine üstünlükleri henüz netlik kazanmamıştır.

Stabilizasyon egzersizleri, kas-iskelet sistemi üzerindeki etkileriyle uyku kalitesini artırabilir. Zambelli vd., yaptığı bir çalışma, uyku kalitesinin ağrı ve depresyon arasındaki ilişkiyi nasıl etkilediğini incelemiştir. Araştırma, iyi bir uyku kalitesinin bu ilişkiyi zayıflattığını ve ağrı ile depresyonun yönetiminde önemli bir hedef olabileceğini göstermiştir.[14] Ayrıca, KBA olan engelli çocukların annelerinde uyku kalitesi ve kaygı düzeylerini iyileştirmek amacıyla stabilizasyon programlarına solunum egzersizlerinin eklenmesi önerilmiştir.[15]

Bir kohort çalışmasında, KBA'nın uyku kalitesi üzerindeki etkileri incelenmiş ve KBA ile uyku kalitesi arasında güçlü ilişki içinde olduğu bulunmuştur.[16] Kronik bel ağrısı ve uyku kalitesi arasındaki ilişki, psikolojik faktörler tarafından da etkilenmektedir. 2020 yılında yapılan çalışma, KBA'nın bireylerin yaşam kalitesini olumsuz etkilediğini ve bunun uyku bozukluklarına yol açtığını bildirmiştir.[17] Uyku hijyeni eğitiminin, uyku kalitesi ve genel sağlık üzerindeki etkileri değerlendirilmiş ve eğitim sonrasında, uyku kalitesinde ve uykusuzluk şiddetinde anlamlı iyileşmeler gözlemlenmiştir.[18]

Literatürde, non-spesifik KBA olan bireylerde zaman içinde oluşan yetersiz uyku kalitesi ve kas-iskelet sistemi ağrıları gibi sorunlar ifade edilmekle birlikte, bu problemleri azaltmaya yönelik uyku hijyeni, kor stabilizasyon egzersizleri ve solunum egzersizlerini bir arada içeren kombine çalışmalara rastlanmamıştır. Bu sebeple, bu çalışma, non-spesifik KBA olan bireylere uygulanan kor stabilizasyon egzersizlerine ek olarak uyku hijyeni ve solunum egzersizlerinin ağrı, ağrıya bağlı özürlülük ve uyku kalitesi üzerindeki etkilerini araştırmayı amaçlamaktadır. Çalışma hipotezi, uyku hijyeni eğitimi, solunum ve kor stabilizasyon egzersizlerinin birlikte uygulanmasının, yalnızca kor stabilizasyon egzersizlerine kıyasla

ağrı şiddeti ve özürlülüğü azaltmada ve uyku kalitesini artırmada daha etkili olduğudur.

YÖNTEM

Hasan Kalyoncu Üniversitesi Sağlık Bilimleri Fakültesi Girişimsel Olmayan Araştırmalar Etik Kurulu'ndan alınan 18.11.2021 tarihinde 2021/031 numaralı onay ile çalışmaya başlandı. Çalışma, DSÖ Uluslararası Klinik Araştırmalar da tescil edildi (Kayıt Platformu-NCT05212753).

Çalışmada gönüllü olan hastalardan çalışmanın amacı ve kapsamı anlatılarak yazılı onay alındı. Çalışmaya KBA tanılı 18-65 yaş arası gönüllü olan, en az 3 ay ağrı geçmişi olan, ağrı seviyesi vizüel analog skala (VAS) da 10 üzerinden 4 ve üzerinde olan ve son 3 aydır medikal tedaviden yararlanmayıp tedavi sürecinde de medikal tedaviye başvurmayacak olan bireyler dahil edildi. Çalışmamıza kökeni bilinen ağrılar, radikülopatiler, VKİ ≥35 kg/m² olanlar egzersiz uygulamalarında kontrendike olan ortopedik, nörolojik, sistemik ya da kardiyopulmoner hastalığı olan, son 3 ay içinde şikayetlerine yönelik bir tedavi almış olan ve egzersizlere uyum sorunu yaşayan bireyler alınmadı.

Çalışmamızda referans alınan çalışmaya göre etki büyüklüğü 0,45, hata düzeyi 0,05 ve testlerin gücü 0,80 kabul edildiğinde çalışmamız için gerekli olan örneklem büyüklüğü her grup için n=17 olarak belirlendi.[19] Örneklem büyüklüğü hesaplaması G*Power Version 3.1.9.6 paket programı ile yapıldı.[20] Çalışmaya 56 hasta ile başlandı. Bireyler rastgele yöntemlerle kapalı zarf usulü kullanılarak üç gruba ayrıldı. Çalışmada 3 grup, 3 hafta süresince KFT kapsamında klinikte yüzeyel sıcaklık ve TENS uygulamasına alındılar. Kontrol grubu (n=18) olan 1. gruptaki bireylere 3 hafta süresince haftada 3 gün sadece KFT programı uygulanırken (KFT grubu), 2. gruptaki bireylere (n=19) KFT programına ilave olarak lumbar stabilizasyon egzersizleri (LSE grubu) eğitimi verildi ve 3 hafta süresince haftada 3 gün, her tedavi seansı toplam egzersiz süresi 20 dakika olmak üzere uygulama yapıldı (Şekil 2). 3. grup bireyler (n=19) ise KFT programı, stabilizasyon egzersizleri ve bunlara ilave olarak uyku hijyeni eğitimi ve solunum egzersizleri (UHSE grubu) öğretildi ve haftada 3 gün, 3 hafta boyunca bu kombine programı uygulamaları istendi. UHSE grubuna solunum egzersizleri için ek süre verilmedi sadece stabilizasyon egzersizlerinin tekrar sayısı azaltıldı. Toplam egzersiz süresi 2. ve 3. gruplarda eşitti ve her seans için 20 dakika olarak uygulandı. Her üç grup hastalara 3 hafta süresince yüzyüze tedavi, KBA da deneyimli olan terapist (S.G) eşliğinde uygulandı. LSE grubu KFT programına ilave olarak sadece stabilizasyon egzersizlerini uygularken, UHSE grubu uyku hijyeni yanında solunum egzersizleri eğitimi aldı ve stabilizasyon egzersizlerini ve hem de günlük yaşam aktivitelerini uygularken kontrollü bir şekilde nefeslerini alıp vermeleri üzerine eğitildi. Bu grup hastalardan, solunum egzersizlerini farkında olarak uygulamaları ve günlük yaşam aktivitelerine uyarlamaları istendi.

LSE ve UHSE grubu bireyler üç haftalık yüzyüze tedavi sonunda, programlarına ilave olarak beş hafta boyunca ev programı olarak devam ettiler. Bu süreçte LSE ve UHSE grubu bireyler ile telefonla beş hafta boyunca haftada bir aranarak iletişime geçildi. Egzersizlerle ilgili yapılamayan, ağrı üreten ya da yapılması hasta tarafından istenmeyen egzersizler hakkında bilgi alındı. Hastaların durumu, egzersizlere devamlılığı, karşılaştıkları zorluklar gibi değişik problemlerde hastalar desteklendi ve alternatifler önerildi. Örneğin, ileri seviye egzersizleri yapamayan hastalara başlangıç seviye egzersizlere geri dönebilecekleri ve hazır olduklarında ileri egzersizlere geçebilecekleri yönünde destek olunarak programlarını devam ettirmeleri hususunda motive olundu.

Çalışma 8 hafta sonunda 52 birey ile tamamlandı (Şekil 1).Tedavi başlangıcında yapılan değerlendirmeler, tedavi sonrası 3. hafta ve takip dönemi olan 8. haftada tekrarlandı. Uygulanan tedavilerin ağrı, özürlülük ve uyku kalitesi ve gündüz uykululuk değerlerini değiştirmede etkili olup olmadığı uygun istatistiksel yöntemler kullanılarak analiz edildi.

Değerlendirmeler

Bireylerin ağrı şiddeti Vizüel Ağrı Skalası (VAS) ve McGill ağrı kısa formu ile ölçüldü. VAS subjektif ağrı değerlendirilmesinde sık kullanılan bir ölçektir. 0 ve 10 aralığında sayıların bulunduğu doğrusal çizgi şeklinde kullanılmaktadır. Bireyden hissettiği ağrıyı çizgi üzerinden işaretlemesi istenir.[21] Bir diğer

ağrı şiddetini ölçtüğümüz McGill ağrı skorları anketi ağrının niteliğini değerlendirmek amacıyla oluşturulmuş, hastanın kendisi tarafından doldurularak cevapladığı bir ağrı ölçeğidir. Türkçe geçerliliği 2007 yılında yapılmış olan anketin ilk kısmında, algısal ağrı boyutu ile duygusal ağrı boyutunu tanımlayan on beş kelime grubu vardır. Bu bölümde, algısal ağrı boyutu 0-33 puan, duygusal ağrı boyutundan 0-12 puan, toplam ağrı boyutundan ise 0-45 puan alınmaktadır. Toplam ağrı puanlarındaki artış, hastanın ağrı seviyesinin arttığını göstermektedir [22].

Bireylerin özürlülük seviyeleri Oswestry Özürlülük İndeksi (OÖİ) ile ölçüldü. OÖİ, ağrıya bağlı özürlülüğü değerlendirmek için geliştirilen 10 soruluk ölçektir.1 soru ağrı ile ilişkilidir. Günlük yaşam aktivitelerini içeren ise 9 soru vardır. Her soru, en iyi durumundan en kötü duruma kadar 6 puanlık bir sıralama ölçeği içerir. Toplam puanın 0-4 olması engelliliğin bulunmadığını, 5–14 olması hafif düzey engellilik durumunu, 15–24 olması orta seviyede engelliliği, 25–34 olması ileri seviye fonksiyonel engelliliği, 35–50 arasında olması ise tam fonksiyonel engelliliği ifade eder.[23] Türkçe olarak geçerlilik ve güvenilirlik çalışması Yakut ve arkadaşları tarafından yapılmış olan form kullanılmıştır.[24]

Bireylerin uyku kalitesi değerleri Pittsburgh Uyku Kalite İndeksi (PUKİ) ile ölçüldü. PUKİ, bir önceki aya göre subjektif uyku kalitesini değerlendiren 19 maddelik bir ölçektir. Bu ölçekteki bireysel 19 madde, uykunun birçok yönünü değerlendiren yedi ayrı bileşende toplanır. Bu yedi bileşenin toplamı, "iyi" ve "kötü" uyku arasında ayrım yapan bir sonuç verir. Ölçeğin toplam puan 0-21 arasında olup, bu toplam puanın 5'ten büyük olması "kötü uyku kalitesini" göstermektedir.[25] Çalışmada Ağargün vd. tarafından 1996'da Türkçe geçerlik ve güvenirlik çalışması yapılmış form kullanılmıştır.[26]

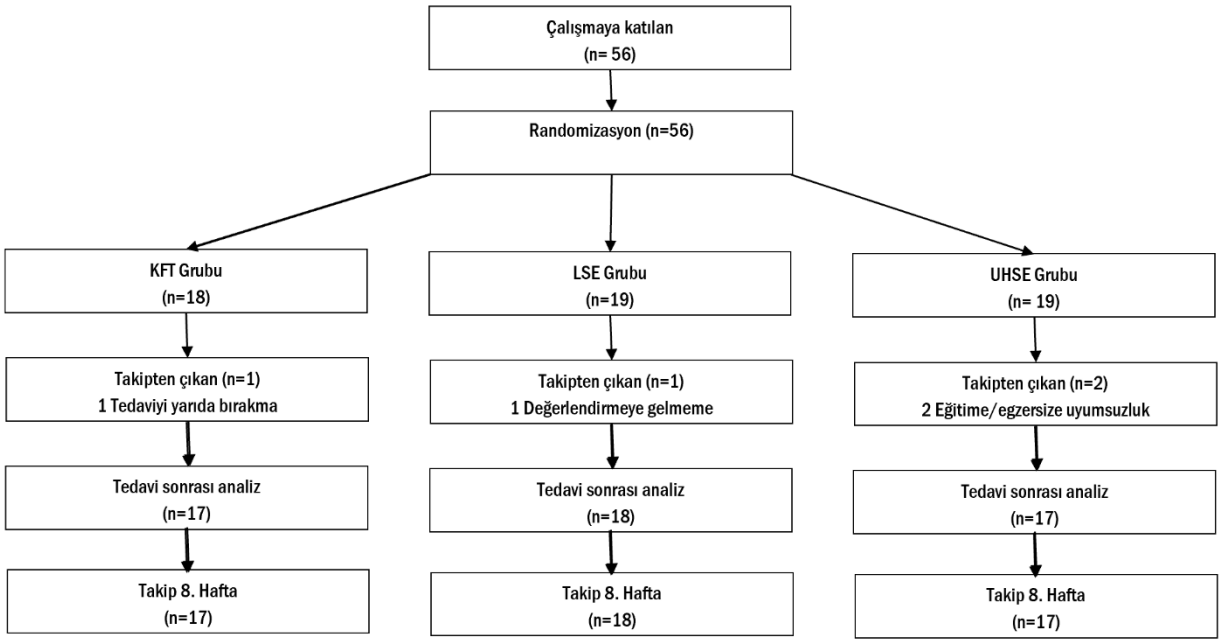
Gündüz uykululuk düzeyleri değerlendirmesi Epworth Uykululuk Ölçeği (EUÖ) ile yapıldı. EUÖ gündüz uykululuk seviyesini değerlendirmek için geliştirilmiş, sekiz soruluk bir ölçektir. Her bir soru için 0-3 arasında değişen dört farklı cevaptan biri seçilir. Total puan 0-5 arasında olduğunda normal gün içi uykululuk seviyesi kabul edilirken 16-24 puan arasında ise şiddetli gün içi uykululuk oranı olarak değerlendirilir. [27] İzci vd. tarafından skalanın Türkçe geçerlik güvenirliği yapılmış olan form kullanılmıştır.[27]

Uygulamalar

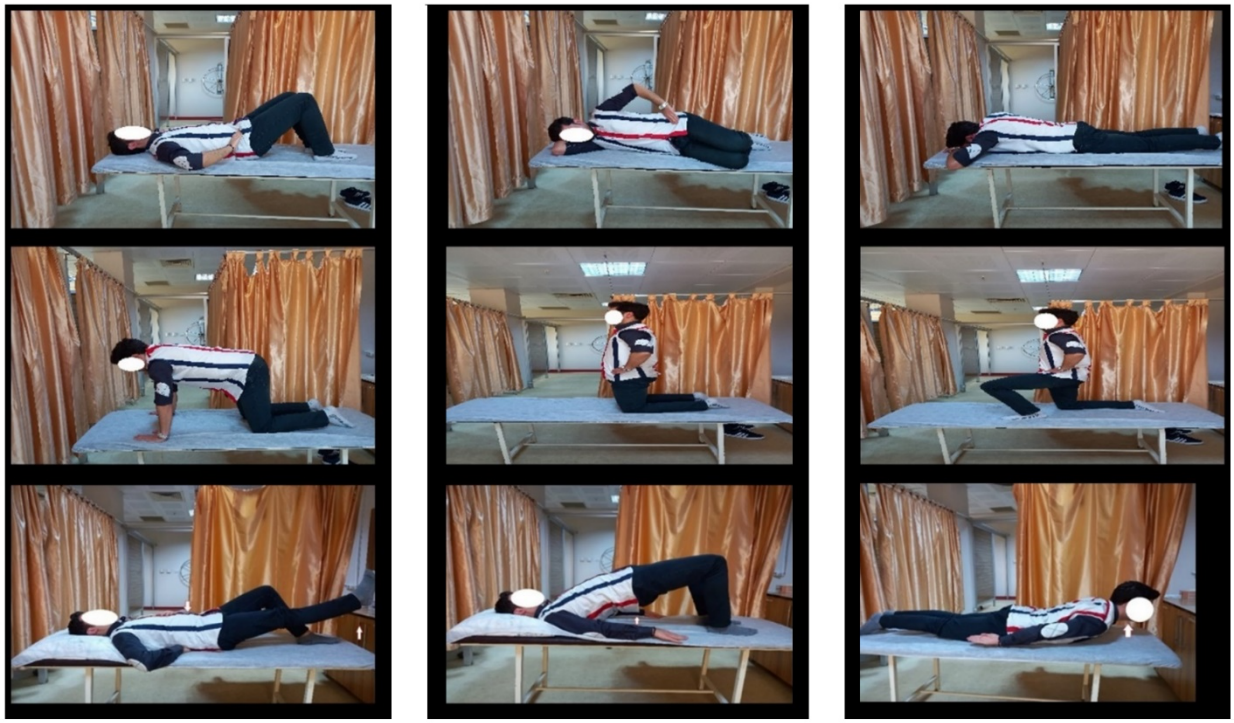
TENS ve Yüzeyel Isı: 4 elektrot ile uygulanan ve 20-40 Hz atım frekansında yaklaşık 90-100 µsn pulse süresi parametreleri kullanılarak uygulanan TENS, toplam 20 dk olmak üzere çalışmaya katılan tüm hastalara uygulandı (Chattanooga Intelect Advanced). TENS uygulamasının yanında KBA olan bireylere tek seferde toplam 20 dk. yüzeyel ısı uygulaması da eklenerek çalışmaya katılan her 3 gruba da uygulandı.[28]

Lumbar Stabilizasyon Egzersizleri: Nötral omurgayı oluşturmayı hedefleyen ve derin spinal kas aktivasyonunu hedef alan lumbar stabilizasyon egzersizleri eğitimlerinde derin spinal kasların reaktivasyonunun sağlanması amaçlandı. Egzersizlere başlamadan önce bireylere stabilizasyon ve abdominal korselemenin anlatıldığı 1 saatlik teorik eğitim ve nötral omurga hakkında anatomik bilgi verildi. Postüral düzgünlük, proprioseptif kontrol kinestetik farkındalık ile transversus abdominus ve multifidus kaslarının fonksiyonları buna ek olarak derin spinal kaslarını nasıl aktive edecekleri hastalara öğretildi.[29] Lumbar bölge multifidus ve transversus abdominus aktivasyonu için "abdominal korse" tekniği ve "abdominal hallowing" teknikleri kullanıldı.[30] Önce sırt üstü yatan bireyler transversus abdominus ve multifidus reaktivasyonu için , dizlerini çengel pozisyonuna alarak el parmaklarını spina iliaka anterior süperiorun biraz altına ve antero-medialine doğru yerleştirir. Hasta derin bir inspirasyondan sonra nefesini verir ve parmaklarına doğru kasıklarını yavaşça kasar. Bu sırada abdominal bölgeyi şişirmemeye, kalçalarını sıkmamaya, nefesini tutmamaya dikkat eder. Sırt üstünde sonra yan yatışta ve yüzüstü pozisyonda ayrı ayrı uygulanır. Başlangıç ve ileri aşama lumbar stabilizasyon egzersizleri hastalara aşamalı olarak öğretildi (Şekil 2 ve 3).

Uyku Hijyeni Eğitimi: UHSE grubundaki hastalara doğru ve sağlıklı uykuyu teşvik etmeyi hedefleyen davranışsal ve çevresel bir dizi faktörlerin uyku üzerindeki olumsuz etkisinin anlatıldığı kapsamlı bir eğitim verildi. Fizyoterapi seansları süresince uyku öncesi değişiklikleri kapsayan yaşam tarzı eğitimi uygulamaya geçirildi. Uyku öncesi kafeinli



Şekil 1. Çalışmanın akış diyagramı.



Şekil 2. Başlangıç stabilizasyon egzersizleri.

Şekil 3. İleri aşama stabilizasyon egzersizleri.

içeceklerden ve nikotinden kaçınmak, uyku öncesi alkolden kaçınmak, uyku öncesi genel duygu durum değişiklikleri ve stresten kaçınmak, uyku saatlerini düzenlemek, gündüz uyuklamaktan kaçınmak ve gürültülü ortamda uykudan kaçınmak olmak üzere 7 ayrı aşamalı uygulamayı kapsayan farkındalık eğitimi verildi.[31,32]

Solunum Egzersizleri: Hastalar solunum egzersizleri için rahat bir pozisyonda hazırlanarak sırtüstü pozisyonda yatırıldı, yastık ile baş ve dizlerin altı desteklendi. Eğer bu pozisyon ağrıyı tetikliyorsa bir yerde oturtuldu. Hastaya diyafram kasının doğru çalışmasını öğretmek için hafif bir kitap karın üzerine yerleştirilip cismin hareketinin nefes alırken yükselmesi, verirken alçalması istendi ve doğru diyafragmatik kasılma sağlandı. Diyafram kasılması öğrenildikten sonra derin bir inspirasyondan sonra dudaklar büzülerek yavaş şekilde ıslık çalar gibi nefes verildi.[33] Ekspirasyonun yavaş yapıldığı ve büzük dudak solunumu olarak adlandırılan bu solunum egzersizini, diyafragmatik solunum ile birleştirmek mümkündür.[27] Dominant olmayan el göğüs üzerinde, dominant el ise göğüs kafesi altında ksifoid çıkıntı ile umblikus arasında yer aldı. Diyafram kasıldı ve abdominal kaslar gevşetilerek karın şişirildi daha sonra da diyafram kası gevşetilerek, abdominal kaslar kasıldı ve karnın geri çekilmesi ile tamamlanarak, dakikada 8-10 tekrar uygulandı.[33,34]

İstatistiksel analiz

İstatistiksel analizlerin tümü, çalışmanın işe kabul, tedavi veya değerlendirme bölümlerine dahil olmayan bir araştırmacı aracılığıyla tamamlanmıştır. Tüm istatistiksel analiz IBM SPSS Statistics 25.0 (SPSS Inc, ABD) programı kullanımı ile yapıldı. Değişkenlerin normal dağılıma uygun olup olmadığı Shapiro-Wilk testi kullanılarak incelendi. Sürekli değişkenler ortalama ± standart sapma ile, kategorik değişkenler ise n (%) ile belirtildi. İkiden fazla zamanlar arası karşılaştırmaların sağlandığı durumlarda Tekrarlı Ölçüm Varyans Analizi, sağlanmadığı durumlarda da Friedman testi yapıldı.

Normallik testine göre bağımsız ikiden fazla grup arasında yapılan karşılaştırmalar Tek Yönlü ANOVA ve Kruskal Wallis testi ile yapıldı. Kategorik değişkenlerin kıyaslanması ise Pearson ki-kare testi ile yapıldı. Veri analizinde anlamlılık düzeyi (yanılma olasılığı) $p<0.05$ kabul edildi. Gruplar arasında zaman içerisindeki değişimlerin istatistiksel olarak anlamlı olup olmadığını değerlendirmek için tekrarlı ölçümler anova tercih edilmiştir. Zamanın ve grup etkileşiminin etkisini değerlendirmek için Greenhouse-Geisser düzeltmesi kullanılmıştır. Analiz sırasında etki büyüklüğü için partial eta squared ($\eta 2$) değerleri rapor edilmiştir. Dikkate alınan etki büyüklüğü değerleri 0,10 = küçük, 0,25 = orta ve 0,40 = büyük kabul edilmiştir.[35]

BULGULAR

Demografik değişkenler karşılaştırıldığında gruplar arasında fark olmadığı, grupların homojen olduğu bulundu ($p>0.05$) (Tablo 1).

Hastaların ağrı değerlendirmeleri VAS ve McGill ağrı ölçeği değerlerinin grup içi ve gruplar arası karşılaştırılması Tablo 2'de görülmektedir. Bel bölgesi VAS ağrı şiddeti skorlarında her üç grupta, tedavi başlangıcına göre anlamlı azalmalar tespit edildi ($p<0.05$). McGill puanında ise KFT grubunda tedavi başlangıcına göre, tedavi sonrası değerlendirmelerde anlamlı azalma bulunmazken ($p>0.05$), LSE ve UHSE gruplarında anlamlı azalma olduğu bulundu ($p<0.05$). Gruplar arası karşılaştırmada, bel VAS değeri ve McGill skorlarında tedavi sonrası fark bulunmazken ($p>0.05$), takip dönemi 8. hafta da gruplar arası anlamlı farklar tespit edildi ($p<0.05$).

Üç grubun özürlülük seviyesi, uyku kalitesi ve gündüz uykululuk değerlerinin grup içi ve gruplar arası karşılaştırılmasında Oswestry özürlülük ve PUKİ uyku kalitesi değerlerinde tüm gruplarda tedavi başlangıcına göre anlamlı azalmalar tespit edildi ($p<0.05$). Epworth gündüz uykululuk değerlerinde LSE ve UHSE gruplarında anlamlı azalmalar elde edilirken ($p<0.05$), KFT grubunda anlamlı azalma olmadı ($p>0.05$).

Ölçeklerin gruplar arası karşılaştırmasında, Oswestry özürlülük indeksi değerinin 8. haftada gruplar arasında anlamlı fark olduğu, UHSE grubunun en düşük skor değerine sahip olduğu görüldü ($p<0.05$). Diğer ölçek puanları ortalamalarında üç grup arasında fark bulunmadı ($p>0.05$) (Tablo 2).

Tablo 3'te, Bel-VAS, McGill Skoru, Oswestry Özürlülük İndeksi (OÖİ), Pittsburgh Uyku Kalite İndeksi (PUKİ) ve Epworth Uykululuk Ölçeği (EUÖ) değerlerinin grup ve zaman etkileşim analizine ilişkin sonuçlar sunulmaktadır. Bel-VAS skorları açısından, grup ve zaman arasındaki etkileşim anlamlı bulunmuş ve özellikle KFT ile LSE grupları arasında eğitim başlangıcı-takip döneminde ($F=18,51$; $p<0,001$; $\eta 2=0,35$) ve KFT ile UHSE grupları arasında eğitim başlangıcı-takip döneminde belirgin farklar tespit edilmiştir ($F=18,37$; $p<0,001$; $\eta 2=0,36$). McGill skorlarında zaman ve grup etkileşimleri açısından KFT ile LSE grupları arasında eğitim başlangıcı-takip döneminde anlamlı farklar görülmüştür ($F=17,43$; $p<0,001$; $\eta 2=0,34$). OÖİ skorlarında da zaman ve grup arasındaki etkileşim anlamlı bulunmuş ve KFT ile LSE grupları arasında ve KFT-UHSE arasında belirgin farklılıklar gözlemlenmiştir ($F=25,11$; $p<0,001$; $\eta 2=0,43$), ($F=18,63$; $p<0,001$; $\eta 2=0,36$), PUKİ skorlarında grup ve zaman etkileşimleri eğitim başlangıcı-takip döneminde genel olarak anlamlı bulunmamakla birlikte, eğitim başlangıcı-takip döneminde KFT-UHSE arasında farklılık gözlenmiştir ($F=7,55$;$p=0,009$; $\eta 2=0,19$). EUÖ değerlerinde ise grup ve zaman arasındaki etkileşim, KFT-UHSE arasında eğitim başlangıcı-takip döneminde istatistiksel olarak orta düzeyde etki göstermiştir ($F=10,16$; $p=0,003$; $\eta 2=0,25$).

TARTIŞMA

Bu çalışmada KBA olan hastalarda uyku hijyeni eğitimi ile solunum egzersizlerinin kor stabilizasyon egzersizlerine katkıları araştırılmıştır. Çalışma sonunda, ağrı şiddeti ve özürlülüğün azaltılması, uyku kalitesinin artırılması ve gündüz uykululuğunun iyileştirilmesi açısından, stabilizasyon egzersizlerine eklenen uyku hijyeni eğitimi ve solunum egzersizlerinin klasik fizyoterapiye kıyasla daha iyi sonuçlar verdiği saptanmıştır. Ancak, yalnızca kor stabilizasyon egzersizlerine

Tablo 1. Çalışma gruplarındaki bireylerin sosyodemografik verilerinin karşılaştırılması.

	KFT Grubu (n=17)	LSE Grubu (n=18)	UHSE Grubu (n=17)	
	X±SD	X±SD	X±SD	p
Yaş (yıl)	39,71±12,78	35,61±12,19	44,29±11,23	0,116
Vücut ağırlığı (kg)	71±11,79	71,33±12,81	71,65±10,16	0,987
Boy (cm)	164,94±8,34	169,67±9,99	167,94±8,64	0,305
Vücut kütle indeksi (kg/m^2)	25,99±3,10	24,62±2,55	25,65±4,67	0,490
	n (%)	n (%)	n (%)	
Cinsiyet (Kadın/Erkek)	10/7 (59/41)	8/10 (44/56)	11/6 (65/36)	0,461
Eğitim durumu				
İlköğretim	4(23,5)	8(44,4)	6(35,3)	0,588
Lise	10(58,8)	6(33,3)	9(52,9)	
Üniversitesi	3(17,6)	4(22,3)	2(11,8)	
Sigara kullanımı				
Evet	5(%29,4)	5(%27,8)	5(%29,4)	1,000
Hayır	12(%70,6)	13(%72,2)	12(%70,6)	

KFT: Klasik Fizyoterapi Grubu. LSE: Lumbar Stabilizasyon Egzersiz Grubu. UHSE:Uyku Hijyeni Solunum Egzersiz Grubu.

Tablo 2. Bireylerin ağrı, özürlülük, uyku kalitesi ve gündüz uykululuk değerlerinin grup içi ve gruplar arası karşılaştırılması.

			Eğitim başlangıcı	Eğitim sonrası	Takip	
			X±SD	X±SD	X±SD	p[a]
Bel- Vizuel Ağrı Skalası	KFT		6,18±1,81	4,24±1,86	4,82±1,74	<0,001
	LSE		6,94±1,92	3,56±1,82	3,22±1,96	<0,001
	UHSE		7,53±1,97	4,06±1,64	4,00±1,58	<0,001
		p[b]	0,126	0,504	0,036*	
McGill Skor	KFT		22,88±7,96	20,24±8,77	21,88±7,39	0,067
	LSE		23,11±8,21	19,17±8,54	16,11±6,25	<0,001
	UHSE		22,59±9,89	18,41±8,80	16,76±7,06	0,003*
		p[b]	0,984	0,829	0,035*	
Oswestry Özürlülük İndeksi	KFT		24,12±5,48	20,82±4,42	22,76±5,25	<0,001
	LSE		25,28±6,42	20,72±5,48	17,28±5,25	<0,001
	UHSE		24,06±6,76	17,82±5,13	16,82±4,10	<0,001
		p[b]	0,808	0,151	0,001*	
Pittsburgh Uyku Kalite İndeksi	KFT		5,35±1,46	4,59±1,42	5,12±1,58	0,041*
	LSE		5,39±2,12	4,22±1,83	4,44±1,85	0,001*
	UHSE		5,24±2,14	4,18±1,51	4,24±2,02	<0,001
		p[b]	0,933	0,716	0,348	
Epworth Uykululuk Ölçeği	KFT		7,12±4,06	6,47±3,47	6,71±3,62	0,099
	LSE		7,44±3,76	6,72±3,44	6,33±3,14	0,047*
	UHSE		7,24±4,55	5,41±3,59	5,35±3,55	<0,001
		p[b]	0,972	0,510	0,500	

*p<0.05; p[a]: Grup içi karşılaştırma. p[b]: Gruplar arası karşılaştırma KFT: Klasik Fizyoterapi Grubu. LSE: Lumbar Stabilizasyon Egzersiz Grubu. UHSE: Uyku Hijyeni ve Solunum Egzersiz Grubu.

Tablo 3. Eğitim başlangıcı, eğitim sonrası ve takip dönemlerinde ağrı, özürlülük, uyku kalitesi ve gündüz uykululuk değerlerinin grup ve zaman etkileşim analizi sonuçları.

	Grup*Zaman Eğitim Başlangıç-Eğitim Sonrası			Grup*Zaman Eğitim Başlangıç-Takip		
	KFT-LSE	KFT-UHSE	LSE-UHSE	KFT-LSE	KFT-UHSE	LSE-UHSE
Bel- Vizuel Ağrı Skalası						
F/p	7,09/0,01	7,83/0,008	0,02/0,87	18,51/0.001	18,37/0,001	0.08/0.76
η^2	0,17	0,19	0,001	0.35	0,36	0.003
McGill Skor						
F/p	0,17/0,47	0,57/0,45	0,01/0,906	17,43/0.001	7,83/0,008	0.31/0.57
η^2	0,02	0,02	0.001	0,34	0.19	0.009
Oswestry Özürlülük İndeksi						
F/p	0,75/0,392	3,74/0,06	0,89/0,34	25,11/0.001	18,63/0,001	0.17/0.67
η^2	0,02	0,10	0.27	0,43	0,36	0.005
Pittsburgh Uyku Kalite İndeksi						
F/p	1,07/0,30	0,56/0,45	0,10/0,74	3,22/0,078	7,55/0,009	0,02/0,88
η^2	0,03	0,02	0,003	0,09	0,19	0,001
Epworth Uykululuk Ölçeği						
F/p	0,02/0,88	7,47/0,01	5,13/0,03	1,60/0,21	10,16/0,003	1,36/0,25
η^2	0,001	0,18	0,13	0,04	0,25	0,04

F: Varyans analizi. η^2: Etki büyüklüğü.

göre anlamlı bir üstünlük sağlanmamıştır. Çalışma başında uyku hijyeni eğitimi, solunum egzersizleri ve kor stabilizasyon egzersizlerinin birlikte uygulanmasının, yalnızca kor stabilizasyon egzersizlerine kıyasla ağrı şiddeti ve özürlülüğü azaltmada ve uyku kalitesini artırmada daha etkili olacağı hipotezi ortaya konmuş, ancak bu hipotez doğrulanmamıştır.

Literatürde, KBA tedavisinde farklı yöntemlerin kullanıldığı görülmektedir. Örneğin, 2017 yılında yapılan bir çalışmada, transkutanöz elektriksel sinir stimülasyonunun (TENS) ağrıyı azaltmada diğer elektroterapi yöntemlerine göre daha etkili olduğu bildirilmiştir. Bu etkinin, TENS'in lumbar bölgedeki nosiseptörler üzerinde lokal etkisi ve kas spazmlarını azaltmasıyla ilişkili olabileceği belirtilmiştir.[36] Ayrıca, solunum egzersizlerinin KBA hastalarında derin gövde kaslarının aktivasyonunu ve solunum fonksiyonlarını iyileştirebileceği, bu nedenle TENS uygulamasına solunum egzersizlerinin eklenmesinin, özellikle non-spesifik KBA olan sporcularda ağrıyı azaltmada daha fazla katkı sağlayabileceği rapor edilmiştir.[34] Sekiz haftalık diyafragmatik solunum eğitiminin, diyafram ve lumbar bölgedeki diğer stabilizatör kasların kalınlığını artırdığı,[34] KBA'lı kadınlarda ise motor kontrol ve stabilizasyon egzersizlerinin ağrı kontrolünde etkili olduğu gösterilmiştir.[12]

Çalışmamızda, hastaların ağrı şiddeti McGill Ağrı Anketi toplam skorlarıyla çok yönlü olarak değerlendirilmiştir. Eğitim başlangıcına kıyasla, 3. hafta ve 8. hafta (takip dönemi) değerlendirmelerinde, KFT grubunda anlamlı bir fark gözlenmezken, LSE ve UHSE gruplarında tüm zaman dilimlerinde toplam ağrı skorlarında anlamlı azalma saptanmıştır. Gruplar arası ikili karşılaştırmalarda, LSE ve UHSE gruplarının 8. haftadaki ağrı skorları açısından birbirine üstün olmadığı belirlenmiştir. Bulgularımız, tek başına kor stabilizasyon egzersizlerinin ağrıyı azaltmada etkili olduğunu göstermektedir. Çalışmada, hastalara tedavi öncesi uyku hijyeni eğitimi verilmiş; 3 haftalık yüz yüze tedavi programında ise kor stabilizasyon ve solunum egzersizleri detaylı bir şekilde uygulamalı olarak öğretilmiştir. LSE grubunda yalnızca kor

stabilizasyon egzersizlerine odaklanılırken, UHSE grubunda stabilizasyon egzersizlerine eklenen solunum egzersizlerinin ağrı üzerindeki etkisi beklenen düzeyde olmamıştır. Bu durum, hastaların solunum egzersizlerini yeterince ya da doğru şekilde uygulamamış olmaları veya stabilizasyon egzersizlerine daha fazla ağırlık vermeleriyle açıklanabilir. Sonuç olarak, solunum egzersizleri ve uyku hijyeni eğitiminin ağrıyı azaltmada kor stabilizasyon egzersizlerinin yerini alamayacağı, ancak destekleyici bir rol oynayabileceği düşünülmektedir.

KBA, dünya genelinde engelliliğin önde gelen nedenlerinden biri olarak kabul edilmektedir.[1,37] Bu durum, fiziksel ve psikolojik bozulmalara, günlük aktivitelerde kısıtlamalara ve toplumsal yaşama katılımda zorluklara yol açarken, önemli bir ekonomik yük oluşturmaktadır.[4,37] Literatürde, solunum egzersizleri ve uyku hijyeni eğitiminin KBA hastalarında ağrıya bağlı özürlülüğe etkisinin kor stabilizasyon egzersizleriyle karşılaştırıldığı bir çalışma bulunmamaktadır. Ancak, KBA yönetiminde kor stabilizasyon egzersizlerinin ağrıya bağlı özürlülüğü azaltmada etkili olduğu bildirilmiştir.[12,38] Kronik bel ağrısında, transvers abdominis ve lomber multifidus kaslarının güçlendirilmesi ile rektus abdominis, dış ve iç oblik kaslar ile erektör spina kaslarının güçlendirilmesi karşılaştırılmış; her iki yöntemin de özürlülük düzeylerini iyileştirmede etkili olduğu, ancak transvers abdominis ve lomber multifidus kaslarının güçlendirilmesinin daha üstün olduğu rapor edilmiştir.[39]

Çalışmamızda, ağrıya bağlı özürlülüğü değerlendirmek için Oswestry Özürlülük İndeksi (OÖİ) kullanılmış ve 8. haftada gruplar arası OÖİ skorlarında anlamlı farklar saptanmıştır. İkili karşılaştırmalarda, LSE ve UHSE gruplarının, KFT grubuna kıyasla OÖİ skorlarında daha fazla azalma gösterdiği belirlenmiştir. Ancak, LSE ve UHSE grupları arasında anlamlı bir fark bulunmamıştır. Kor stabilizasyon egzersizlerine eklenen solunum egzersizleri ve uyku hijyeni eğitimi, yalnızca stabilizasyon egzersizleri uygulayan gruba göre ağrıya bağlı özürlülüğün azaltılmasında ek bir katkı sağlamamıştır. Uyku hijyeni, sağlıklı alışkanlıklar kazandırmayı amaçlayan bir eğitimdir. Ancak çalışmamızda, hastaların bu alışkanlıkları sürdürmedeki istikrarı değerlendirilmemiştir. Bu sonuçlara dayanarak, non-spesifik KBA hastalarında, klinisyenin deneyimi ve hastanın tercihleri doğrultusunda, ağrıya bağlı özürlülüğün tedavisine uyku hijyeni eğitimi ve solunum egzersizlerinin dahil edilmesini ve bu uygulamaların yakından takip edilmesini önermekteyiz.

Uyku bozuklukları, kronik kas-iskelet sistemi şikâyeti olan hastalarda sık görülen bir sorundur. Ağrı ve uyku bozuklukları arasında bir kısır döngü bulunmakta; ağrı uyku kalitesini bozarken, düşük uyku kalitesi de ağrıyı artırabilmektedir. Toplam uyku süresinden ziyade uyku kalitesinin daha önemli olduğu ve düşük uyku kalitesinin bel ağrısı nedeniyle sağlık hizmetlerine başvurmanın bir nedeni olduğu gösterilmiştir.[40] Kronik ağrı, merkezi duyarlılaşma ve uyku bozuklukları arasındaki ilişki, literatürde çeşitli çalışmalarla vurgulanmaktadır.[41,42] Örneğin, diz osteoartriti olan hastalarda komorbid uykusuzluk varlığında daha yüksek merkezi duyarlılaşma bildirilmiştir.[31] Benzer şekilde, kronik ağrılı 961 kişilik bir örneklemde, ağrıya bağlı uyku sorunlarının ağrı duyarlılığı ile güçlü bir ilişkisi olduğu saptanmıştır.[42] Araştırmacılar, ağrı duyarlılığını azaltarak ağrının hafiflemesine katkıda bulunabilecek uyku kalitesinin iyileştirilmesinin önemini vurgulamıştır.[41,42] Ayrıca, uyku ve nöro-immünoloji alanındaki mevcut bilgiler, uyku bozuklukları ile ağrı arasındaki olası bağlantıları desteklemektedir. Sağlıklı uyku, bağışıklık fonksiyonlarını desteklerken, bozulmuş uyku kalitesi veya miktarı, inflamatuar yanıtları tetikleyebilir.[31]

Uyku kalitesi; ağrı, bireyin uyku alışkanlıkları, kaygı düzeyi ve eşlik eden sorunlardan etkilenmektedir. [5,11,41] Çalışmalar, kronik ağrı hastalarında merkezi duyarlılaşma ile uyku bozuklukları arasında güçlü bir ilişki olduğunu göstermektedir. Ayrıca, sağlıklı bireylerde uyku kısıtlamasının spontan ağrıyı artırdığı, yetersiz ve kalitesiz uykunun ise ağrı eşiğini düşürerek hiperaljeziye katkıda bulunduğu belirtilmiştir.[41,42] Örneğin, Büyük Japonya Depremi sonrası yapılan bir uzun vadeli çalışmada, felaketten etkilenen bölgelerde yaşayan 2097 bireyin verileri analiz edilmiş ve bel ağrısı ile uyku bozukluğu arasında güçlü bir ilişki olduğu saptanmıştır. Araştırmacılar, uyku bozukluklarını önlemek ve tedavi etmek için bel ağrısının erken dönemde

ele alınması ve kronikleşmesinin engellenmesi gerektiğini vurgulamıştır. [43]

2018 yılında yayınlanan bir çalışma, non-spesifik KBA olan hastalarda uyku kalitesinin önemi vurgulamış ve kor stabilizasyon egzersizlerinin uyku bozukluğu yönetiminde etkili bir yöntem olduğunu bildirmiştir.[44] Uyku kalitesi, ağrının yanı sıra bireyin uyku alışkanlıkları, kaygı düzeyi ve eşlik eden diğer problemlerden de etkilenmektedir.[45] Uyku hijyeni gibi kendine bakım önerilerinin, uyku sorunları için birinci basamak müdahale olarak uygulanabileceği belirtilmiştir.[31,45]

Uyku hijyeni eğitimi genel topluma tek başına uyku kalitesini ya da uyku bozukluklarını iyileştirmedeki etkinliği henüz kanıtlanmamış bir yaşam değişikliğidir. Çalışmamızda, uyku hijyeni eğitimi, kor stabilizasyon ve solunum egzersizleriyle birlikte uygulanmıştır. Böylece, bel ağrısının uyku bozukluğuna yol açan birincil etkeni tedavi edilirken, uyku kalitesini etkileyebilecek diğer faktörlerin de kontrol altına alınması sağlandı. Bu yaklaşım ile uyku bozukluğunun ağrıya katkıya bulunmasının önüne geçmesi hedeflendi. Uyku kalitesini değerlendirmek için kullandığımız PUKİ toplam puanın ≥5 olması, uyku kalitesinin bozuk olduğunu göstermektedir; daha yüksek puanlar daha kötü uyku kalitesine işaret eder.[25] Çalışmamızda, KBA olan tüm hastaların tedavi başlangıcında uyku kalitesinin düşük olduğu saptanmıştır.

UHSE grubunda, kor stabilizasyon egzersizlerine ek olarak uygulanan uyku hijyeni eğitimi ve solunum egzersizleriyle, hastaların ağrı şiddeti ile uyku kalitesi arasındaki ilişkiye dikkatleri çekilmeye çalışılmıştır. Hastalardan, basit ancak farkındalık oluşturacak önerileri düzenli olarak uygulamaları istenmiştir. Tedavi sonrası gruplar arası karşılaştırmada, LSE ve UHSE gruplarının, KFT grubuna kıyasla uyku kalitesini artırmada daha etkili olduğu belirlenmiştir. LSE ve UHSE gruplarında, tedavi sonrası 3. hafta ve takip 8. hafta değerlendirmelerinde PUKİ skorlarında anlamlı azalma, yani uyku kalitesinde artış gözlenmiştir. Üç haftalık yüz yüze eğitim ve ardından beş haftalık ev egzersiz programının, her iki grupta da uyku kalitesini iyileştirdiği saptanmıştır. Ancak, uyku hijyeni ve solunum egzersizlerinin eklenmesi, yalnızca kor stabilizasyon egzersizleri uygulayan gruba kıyasla uyku kalitesini artırmada anlamlı bir ek katkı sağlamamıştır. Literatürle uyumlu olarak, çalışmamızda ağrı düzeyleri ile uyku kalitesinin paralel seyrettiği bulunmuştur. Kor stabilizasyon egzersizlerine eklenen uyku hijyeni eğitimi ve solunum egzersizlerinin, hasta takibiyle düzenli olarak uygulanması durumunda tamamlayıcı bir tedavi yöntemi olarak faydalı olabileceği düşünülmektedir.

Uyku kalitesindeki artış, dolaylı olarak gündüz uykululuk düzeyinde azalmaya yol açacaktır. Yetişkinlerde gündüz uykululuğunu değerlendirmek için kullandığımız EUÖ, Cronbach's alpha >0.86 ile yüksek iç tutarlılığa sahip bir ankettir ve Uyku Fonksiyonel Sonuçları Anketi ile güçlü bir korelasyon gösterdiği bildirilmiştir.[21] Çalışmamızda, kor stabilizasyon egzersizlerine eklenen uyku hijyeni eğitimi ve solunum egzersizlerinin gündüz uykululuğunu azaltmada katkı sağladığı saptanmıştır. LSE ve UHSE gruplarında, EUÖ skorları tedavi sonrası anlamlı ölçüde azalmış ve takip döneminde de sürdürdüğü görülmüştür. Eğitim başlangıcı ile takip dönemi arasında, UHSE grubunun gündüz uykululuğunu azaltmada KFT grubuna kıyasla daha etkili olduğu belirlenmiştir. Etki büyüklüğünün orta düzeyde olması ($\eta^2 = 0.25$), UHSE programının uykululuk yönetimindeki potansiyel etkisine işaret etmektedir. UHSE programında kullanılan kapsamlı stratejilerin, bireylerin uykululuk algısını ve uyku düzenini iyileştirmede daha başarılı olabileceği düşünülmektedir. Ancak, bu bulgunun daha geniş örneklemlerle ve uzun vadeli takip çalışmalarıyla desteklenmesi gerekmektedir.

Limitasyonlar

Çalışmamızda bazı limitasyonlarımız bulunmaktadır. KFT grubuna uygulanan tedavi süresi, kurum politikası nedeniyle 3 haftayla sınırlı kalmıştır. LSE ve UHSE gruplarına uygulanan 5 haftalık takip süreci, KFT grubuna uygulanamamıştır. Bu durum, KFT grubunun kısa vadede tedaviden fayda sağlamasına olanak tanımış, ancak uzun vadeli etkilerin tam olarak değerlendirilmesini engellemiştir. Bir diğer limitasyonumuz bireylerin uyku alışkanlıklarının detaylı bir şekilde değerlendirilmemiş olmasıdır. Gelecekte yapılacak çalışmalarda, gruplar arasındaki tedavi sürelerinin ve ev programlarının dengeli bir şekilde planlanması ile bireylerin uyku alışkanlıklarının kapsamlı bir şekilde

incelendiği uzun vadeli karşılaştırmalı araştırmalara ihtiyaç vardır.

Sonuç

Çalışmamız, kor stabilizasyon egzersizleri, uyku hijyeni eğitimi ve solunum egzersizlerinin ağrı, özürlülük ve uyku parametreleri üzerinde olumlu etkiler yarattığını göstermiştir. Ancak, kor stabilizasyon egzersizlerine eklenen uyku hijyeni eğitimi ve solunum egzersizleri, non-spesifik KBA olan hastalarda ağrıya bağlı özürlülüğü ve uyku kalitesini artırmada, yalnızca stabilizasyon egzersizlerine kıyasla ek bir katkı sağlamamıştır. Kor stabilizasyon egzersizlerinin, ağrı, özürlülük ve uyku parametreleri üzerinde tek başına etkili olduğu saptanmıştır. Buna karşılık, TENS ve yüzeyel sıcaklık uygulamalarını içeren KFT grubu, yalnızca palyatif bir etki göstermiş; takip döneminde bu grupta özürlülük skorlarında anlamlı bir artış gözlenmiştir. UHSE programının gündüz uykululuğunu azaltmadaki etkisi, yapılandırılmış ve yoğun programların bireylerin yaşam kalitesini iyileştirmedeki önemini vurgulamaktadır. Bu bulgu, özellikle uyku bozuklukları ve gündüz performans düşüklüğünden etkilenen bireyler için UHSE programının tercih edilebileceğini göstermektedir.

Çalışmamızın, kronik ağrı alanında çalışan klinisyenlere rehber olacağı düşünülmektedir. KBA hastalarında sık görülen uyku sorunları göz önüne alındığında, tedavi programlarına uyku hijyeni eğitimi ve solunum egzersizlerinin eklenmesi, bütüncül bir tedavi yaklaşımı kapsamında fayda sağlayabilir. Uyku hijyeni eğitimi ve terapötik egzersizler, literatürde önerilen KBA tedavi yaklaşımlarıyla entegre edilmelidir. Eğitim ve egzersiz programları, hastalarla yakın etkileşim kurularak uygulandığında, ağrıya bağlı uyku sorunları konusunda farkındalığı artırabilir. Çalışmamızın bulguları, daha uzun süreli ve farklı egzersiz ile tedavi yaklaşımlarını karşılaştıran çalışmalarla desteklenerek geliştirilmelidir.

Teşekkür: *Yok*

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ORIGINAL ARTICLE

Comparison of characteristic features and quality of life in faller and non-faller transtibial prosthesis users

Düşen ve düşmeyen transtibial protez kullanıcılarında karakteristik özelliklerin ve yaşam kalitesinin karşılaştırılması

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Abstract

Purpose: Falls and fall-related injuries are common among lower limb prosthesis users. However, the reasons of falls and their impact on health-related quality of life in transtibial prosthesis users (TTPU) remain unclear. We aimed to compare the characteristic differences and quality of life between faller and non-faller TTPU.
Methods: Thirty-six TTPU participated in the study. Subjects who had fallen at least once in the past year were classified as fallers. Functional levels were assessed using the Two-Minute Walk Test, the Timed Up & Go Test, and the Functional Reach Test.
Results: Sixteen (44.44%) participants were identified as fallers. Fallers had higher age and had longer TUG test durations compared to non-fallers ($p<0.05$). Differences in working status, reason for amputation, prevalence of diabetes, and walking aid use were significant between fallers and non-fallers ($p<0.05$). Quality of life levels were similar between the groups ($p>0.05$).
Conclusion: Older age, decreased functional level, not working, having a vascular amputation, having diabetes, and using any walking aid were identified as the characteristic differences of faller transtibial prosthesis users.
Keywords: Amputation, Prosthesis, Falls, Quality of life

Öz

Amaç: *Alt ekstremite protezi kullanıcılarında düşmeler ve düşmeye bağlı yaralanmalar yaygındır. Transtibial protez kullanıcılarında (TTPK) düşme nedenleri ve bunların sağlıkla ilişkili yaşam kalitesi üzerindeki etkisi net değildir. Bu çalışmada, düşen ve düşmeyen TTPK arasındaki karakteristik farklılıkları ve yaşam kalitesini karşılaştırmayı amaçladık.*
Yöntem: *Çalışmaya 36 TTPK katıldı. Son bir yıl içinde en az bir kez düşen bireyler düşenler olarak sınıflandırıldı. Fonksiyonel seviye, İki Dakika Yürüme Testi, Süreli Kalk Yürü Testi ve Fonksiyonel Uzanma Testi ile değerlendirildi.*
Bulgular: *Katılımcıların 16'sı (%44,44) düşen olarak belirlendi. Düşenlerin yaşı daha yüksekti ve Süreli Kalk Yürü Testi süreleri daha uzundu ($p<0,05$). Çalışma durumu, amputasyon nedeni, diyabet prevalansı ve yürüme yardımcısı kullanımı açısından düşenler ile düşmeyenler arasında anlamlı farklılıklar bulundu ($p<0,05$). Gruplar arasında yaşam kalitesi seviyeleri benzerdi ($p>0,05$).*
Sonuç: *İleri yaş, azalmış fonksiyonel seviye, çalışmama durumu, vasküler nedenli amputasyon, diyabet varlığı ve yürüme yardımcısı kullanımı düşen transtibial protez kullanıcılarındaki karakteristik farklılıklardır.*
Anahtar Kelimeler: *Amputasyon, Protez, Düşmeler, Yaşam kalitesi*

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INTRODUCTION

Reduced mobility in individuals with lower limb prostheses can lead to falls and fall-related injuries.[1,2] The annual fall rate in this population exceeds 50%.[3,4] These falls often result in negative consequences such as injury, financial loss, decreased mobility, and reduced quality of life.[5-9] Therefore, it is crucial to identify the reasons of falls among lower extremity prosthesis users and take necessary precautions to prevent secondary issues.

Risk factors for falling can vary between the early and late periods following lower limb amputation. Yu et al. associated falls during the early in-hospital period with vascular etiology, transtibial amputation level, and right-sided amputation.[10] In contrast, Pauley et al. identified factors such as age over 70 years, comorbidities, prolonged hospital stay, polypharmacy, cognitive impairment, and bilateral amputation as risk factors for falls in individuals undergoing rehabilitation.[11] In the late period, different studies have identified transfemoral amputation level, pain, amputation duration of less than 4 years, stump problems, decreased muscle strength, and reduced vibration sense as risk factors for falls.[1,12,13]

Although transfemoral amputees are known to be at greater risk of falling, the proportion of falls and fall-related injuries among transtibial amputees is also significant.[5,12,14] Studies on falls in transtibial prosthesis users (TTPU) typically assess gait variability and balance.[12,13,17] TTPU who have fallen exhibit greater variability in step length, step width, step time, and swing phase compared to those who have not fallen.[15,16] While some studies associate reduced dynamic balance with falls in TTPU, other studies have shown similar balance abilities between fallers and non-fallers.[12,13,17] Gait and balance can also be influenced by the type of prosthesis used. Previous researches have demonstrated the positive effects of vacuum-assisted transtibial prostheses on balance and gait, but their impact on falls remains unknown.[18,19]

Studies examining falls in lower limb prosthesis users are insufficient to provide clear information about TTPU because they often include different amputation levels. Few studies have explored the spatio-temporal characteristics of gait and balance in TTPU. Additionally, no studies have reported the health-related quality of life (HRQoL) of TTPU who have fallen. Therefore, the aim of this study is to investigate the characteristic differences and the quality of life between fallers and non-fallers.

METHODS

This descriptive cross-sectional study was conducted among TTPU at an outpatient clinic between August 2023 and December 2023. The research protocol was approved by the Eastern Mediterranean University Research and Publication Ethics Board (decision number 2023/011), and all participants signed informed consent forms. This trial was registered on ClinicalTrials.gov with the number NCT05999539 before it started.

Inclusion criteria for the study were: being over 18 years of age, using a transtibial prosthesis for at least one year, and being able to walk independently (with or without a walking aid) for at least 30 meters. Exclusion criteria included the use of multiple prostheses, discomfort with the prosthesis, or having a wound on the stump. The effect size was calculated using the G-Power program (Version 3.1.9.2, Kiel University, Germany) with an effect size of d:1.01, based on the Timed Up and Go (TUG) duration of the first 10 participants (5 fallers, 5 non-fallers). To achieve a power of β:0.80 at a significance level of α=0.05, the required sample size was determined to be 34 participants.

Procedure

Participants who had fallen at least once in the past year were classified as fallers. Data collected included age, gender, body mass index, reason for amputation, side of amputation, marital and working status, comorbidities such as diabetes, hypertension and hyperlipidemia, time since amputation, phantom sensation and pain, type of prosthesis, and use of assistive devices. Gait and balance performance were assessed using the Two-Minute Walk Test (2MWT), Timed Up and Go Test (TUG), and Functional Reach Test (FRT).

In the 2MWT, participants were asked to walk a 30-meter distance repeatedly for two minutes, and the distance walked was recorded

in meters.[20] In the TUG test, participants were asked to rise from a chair with a seat height of 46 cm, walk 3 meters, turn 180 degrees, return to the chair, and sit down.[21] The time taken was recorded in seconds using a stopwatch. In the FRT, participants stood with their dominant limb against a wall and reached forward with an arm flexed at 90 degrees and elbow extended.[22] The difference between the start and end points of the distal third finger was measured, and the best result of three attempts was recorded in centimeters.

HRQoL was assessed using the psychosocial adjustment, activity limitation, and satisfaction with the prosthesis subdomains of the Trinity Amputation and Prosthesis Experiences Scales (TAPES).[23]

Statistical analysis

Data analysis was performed using SPSS 20.0 (Statistical Package for the Social Sciences, IBM, USA). The normality of data distribution was examined using the Shapiro–Wilk test and histogram graphics. For comparisons between groups, the independent t-test was used for normally distributed data, while the Mann-Whitney U test was used when parametric conditions were not met. The significance level was set at $p < 0.05$, and results were presented as mean ± standard deviation (Mean ± SD) with minimum and maximum values. Optimal cut-off values were defined using the Index of Union method after Receiver Operating Characteristics (ROC) curve analysis for variables with significant differences.[24] The 2x2 Chi-square Test was used for comparisons of categorical variables, with results reported as n (%).

RESULTS

Out of the 36 TTPU included in the study, 16 (44.44%) were identified as fallers. The age and TUG test duration of the fallers were significantly higher than those of the non-fallers ($p<0.05$). ROC analysis determined cut-off values of 50.50 years for age (sensitivity: 0.938, specificity: 0.450, AUC: 0.728) and 8.14 seconds for TUG (sensitivity: 0.875, specificity: 0.500, AUC: 0.719). No significant differences were found between the two groups in terms of BMI, FRT, 2MWT, and TAPES results ($p>0.05$, Table 1). There were significant differences in working status, reason for amputation, prevalence of diabetes, and walking aid use between fallers and non-fallers ($p<0.05$, Table 2).

DISCUSSION

Authors According to the results of our study, being over 50 years old, having a TUG test time of more than 8.14 seconds, not working, having a vascular amputation, having diabetes, and using any walking aid were identified as the characteristics of faller TTPU. Interestingly, health-related quality of life (HRQoL) levels were found to be similar between fallers and non-fallers. To our knowledge, this is the first study to compare HRQoL between fallers and non-fallers among TTPU. Although no significant difference was observed in quality of life scores between the groups, this finding is noteworthy. It should be noted that, the sensitivity of the TAPES scale in detecting subtle differences related to fall experience may be limited, particularly in small or homogeneous samples. In addition, HRQoL in amputees may be influenced by various factors such as gender, age, cause of amputation, phantom pain, ability to use a prosthesis, physical function, depression, anxiety, body image, and type of prosthesis, as described in the systematic review by Maciver et al.[25] The similarity between the two groups in terms of factors such as gender, phantom pain, and type of prosthesis evaluated in our study may also help explain the absence of a significant difference in HRQoL.

Previous studies have reported that the incidence of falls in TTPU ranges from 27-61%.[12,15] Notably, the primary difference between these studies is the age of the participants. Clemens et al. found a fall rate of 27% with a mean age of 47.1 years, while Parker et al. found a fall rate of 61% in individuals with a mean age of over 60 years.[12,15] In our study, the fall rate was 44.44% among individuals with a mean age of 55.33 years. These results suggest that age may be a risk factor for falling among TTPU. This is further supported by the high rate of falls in individuals over 50 in our study. Older age is known to be an important risk factor for falls in people without prostheses. Data from studies conducted in our country

Table 1. Comparison of demographic characteristics, functional performance, and TAPES between fallers and non-fallers.

	Faller (N=16)	Non-Faller (N=20)	
	X±SD	X±SD	p
Age (years)	61.82±9.62	50.13±15.94	0.010*
Body Mass Index (kg/cm²)	27.53±4.14	24.94±3.53	0.051
Time Since Amputation (years)	6.43±8.02	12.57±14.32	0.168
The Timed Up & Go Test (sec)	9.96±2.02	8.34±2.10	0.026*
Functional Reach Test (cm)	28.43±8.84	30.35±11.50	0.589
2 Min. Walk Test (m)	127.24±22.25	143.83±28.35	0.063
TAPES	110.02±27.91	113.53±12.32	0.613
Psychosocial Adaptation	49.50±9.76	52.24±8.54	0.383
Activity Restriction	14.84±8.93	20.12±7.89	0.118
Satisfaction with the Prosthesis	39.24±8.56	43.04±7.29	0.077

*p<0.05. TAPES: Trinity Amputation and Prosthesis Experiences Scales.

Table 2: Comparison of demographic, clinical, and prosthetic characteristics between groups.

		Faller (n=16)	Non-Faller (n=20)	
		n (%)	n (%)	p
Gender	Female	5 (31.25)	6 (30)	0.936
	Male	11 (68.75)	14 (70)	
Age (years)	≤50	1 (6.25)	11 (55)	0.002*
	>50	15 (93.75)	9 (45)	
Timed Up & Go Test (sec)	≤8.14	2 (12.50)	10 (50)	0.018*
	>8.14	14 (87.50)	10 (50)	
Marital status	Married	11 (68.75)	17 (85)	0.422
	Single	5 (31.25)	3 (15)	
Working Status	Working	1 (6.25)	13 (65)	<0.001
	Not working	15 (93.75)	7 (35)	
Amputation Side	Left	7 (43.75)	13 (65)	0.202
	Right	9 (56.25)	7 (35)	
Reason for Amputation	Non-vascular	4 (75.00)	12 (60)	0.036*
	Vascular	12 (25.00)	8 (40)	
Diabetes	Yes	14 (87.50)	5 (25)	<0.001
	No	2 (12.50)	15 (75)	
Hypertension	Yes	6 (37.50)	3 (15)	0.146
	No	10 (62.50)	17 (85)	
Hyperlipidemia	Yes	2 (12.50)	0 (0)	0.190
	No	14 (87.50)	20 (100)	
Walking aid use	Yes	8 (50)	1 (5)	0.005*
	No	8 (50)	19 (95)	
Suspension System	Pin lock	11 (68.75)	9 (45)	0.154
	Vacuum assisted	5 (31.25)	11 (55)	
Prosthetic Foot Type	Energy storing (Carbon)	3 (18.75)	10 (50)	0.052
	Others	13 (81.25)	10 (50)	
Phantom Sense	Yes	9 (56.25)	13 (65)	0.400
	No	7 (43.75)	7 (35)	
Phantom Pain	Yes	5 (31.25)	9 (45)	0.593
	No	11 (68.75)	11 (55)	

* p<0.05.

show that the fall rate in the geriatric population is 33-36% and 80% in geriatric amputee population.[26,27] These results indicate that the faller rate increases at an earlier age in lower limb prosthesis users.

Interestingly, some previous studies found no age difference between faller and non-faller lower limb prosthesis users. This may be explained by the different reasons and levels of amputation or age groups of participants in those studies. Clemens et al. did not find an age difference between faller and non-faller TTPU, only in non-vascular amputees with a relatively lower mean age.[12] The high rate of vascular amputation and diabetes comorbidity in the faller group in our study may explain the increase in the rate of falls with increasing age. On the other hand, Miller et al. found neither age nor reason for amputation to be a risk factor for falls in lower limb amputees.[3] The difference in their study is that they worked with a large sample including transfemoral amputations. The inclusion of transfemoral amputees may have eliminated the influence of other factors. This is supported by the finding that transfemoral amputation is an important fall risk factor in the same study.

Conversely, Wong et al. did not find the level of transfemoral amputation to be a risk factor in their study of the American population, but they showed that the risk of falls increased with age in the transfemoral group.[14] Additionally, they found that the risk of falls was lower in amputees with vascular causes. These differences between populations may be related to the activity and participation levels of individuals, which have not been assessed in studies. The authors also discussed that transtibial or traumatic amputees may engage in more risky activities, increasing the risk of falls. In the same study, the authors showed that vascular comorbidity, rather than vascular etiology, was an important risk factor. Dite et al. also identified having four or more comorbidities as a factor increasing the frequency of falls in TTPU.[17] Diabetes mellitus, which had not previously been analyzed as a separate risk factor in transtibial amputees, was found to be more prevalent in the faller group in our study. Diabetes-related neuropathy is known to adversely affect balance and increase the risk of falling in the non-amputee population.[28] It is therefore not surprising that the presence of diabetes mellitus is more common in transtibial fallers. The fact that the rates of hyperlipidaemia and hypertension were similar between fallers and non-fallers in our study suggests that the presence of diabetes may be the most important comorbidity causing falls.

In our study, a TUG test time of more than 8.14 seconds was also identified as a discriminator for falls. Similarly, Sawers et al. found ≥8.17 seconds as the cut-off for the TUG test in lower limb prosthesis users.[4] These results indicate that the TUG test is a valuable assessment tool for determining fall risk in lower extremity prosthesis users. In addition, when interpreting the cut-off values obtained for TUG time and age in our study, the sensitivity and specificity values should also be taken into consideration. Although a TUG time of ≥8.17 seconds or an age of >50 years can predict fall risk with high sensitivity, the low specificity indicates that some individuals without fall risk may be misclassified as at risk. Therefore, these criteria alone may not be sufficient to accurately determine fall risk. On the other hand, we found that the 2MWT distance was similar between fallers and non-fallers. Similarly, a previous study found no difference in gait speed between fallers and non-fallers among TTPU. However, they observed that gait step regularity was lower in fallers.[15] Also, in non-amputee geriatric individuals, gait irregularity rather than walking speed is associated with falls.[29] These results may explain the similar walking speeds between fallers and non-fallers. In addition, our study only assessed fall history; however, as previously reported by Miller et al., fear of falling may also be present in non-fallers.[3] The similarity in walking speed between groups may, in part, be attributed to the presence of fear of falling in the non-faller group. Future studies would benefit from including assessments of fear of falling to provide a more comprehensive understanding of walking speed and fall risk.

Another important finding of our study was the high rate of walking aid users among fallers. Walking aids are used to ensure mobility and prevent falls in prosthesis users with poor balance. However, the effect of walking aid use on fall prevention among lower limb prosthesis users is unknown. The use of a walking aid may even be a factor that increases the risk of falls. In the fall prevention guidelines for the non-

amputee older population, the use of walking aids is among the risk factors for falls with a high level of evidence.[30] Therefore, it is crucial that walking aids are selected and used appropriately. Future studies should investigate falls caused by walking aids in lower limb prosthesis users.

Previous studies have shown that vacuum-assisted transtibial prostheses improve balance and gait and may be effective in preventing falls.[18,19] In our study, there was no difference in the fall percentages between participants using vacuum-assisted and pin-lock systems. It is important to remember that our study did not inquire about the number of falls. Even if the type of prosthesis does not completely prevent falls, it may reduce the number of falls and fall-related injuries. It should also be noted that only two different types of suspension were included in our study.

Working status also differed between fallers and non-fallers in our study. This was only questioned in Miller et al.'s study, which did not find it to be a fall risk factor.[3] The difference found in our sample may be due to the fact that we included only transtibial users with a relatively lower mean age than their sample. Being an active worker can play a role in preventing falls by maintaining functional level and preventing comorbidities. They also found that having joint and back pain were risk factors for falls. In our study, phantom sensation and pain were questioned but no difference was found. Mechanical pain, which was not assessed in our study, may be associated with falls due to its relationship with activity on prosthesis. In future studies, it would be beneficial to determine factors that increase the risk of falls among TTPU by conducting regression analysis on a larger sample, taking into consideration the characteristic differences we have identified.

Limitations

The limitations of our study include the retrospective questioning of fall status over the past year, which may have led to recall bias. In addition, the lack of detailed inquiry regarding the frequency of falls and fall-related injuries limits the interpretation of our findings. Moreover, due to our inadequate sample size for conducting regression analysis, we were not able to identify which factors constitute a definite risk for falls. As only TTPU were included in our study, it has unique results in terms of showing the differences in this population.

Conclusion

Older age, decreased functional level, not working, having a vascular amputation, having diabetes, and using any walking aid were identified as the characteristics in faller TTPU. Falls had no effect on HRQoL in this group.

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Authors' Contributions: **YY:** Concept/idea development, study design, project management, data analysis/interpretation, literature search, provision of facts, provision of facilities/equipment, writing, critical review; **CK:** Study design, data collection/processing, literature search, provision of facilities/equipment, writing, critical review; **ÖÇ:** Study design, data collection/processing, literature search, provision of facilities/equipment, writing, critical review; **TP:** Data collection/processing, literature search, writing, critical review; **MP:** Data collection/processing, literature search, writing, critical review.

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ORIGINAL ARTICLE

Çocukluk çağı kanseri tanılı çocuklar ve adölesanların aktivite performansını etkileyen katılım kısıtlılıklarının incelenmesi

Examination of participation limitations affecting the activity performance of children and adolescents diagnosed with childhood cancer

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Öz

Amaç: Bu tanımlayıcı çalışmada, kanser tanısı almış çocuk ve adölesanların aktivite performansını etkileyen katılım kısıtlılıklarının incelenmesi amaçlandı.

Yöntem: Çalışmaya kanser tanısı almış ve bir yıldan uzun süredir tedavi gören 62 (yaş ortalaması 10,07± 3,83 yıl) ve sağlıklı 54 (yaş ortalaması 9,29±3,43 yıl) çocuk ve adölesan katıldı. Aktivite performansını etkileyen katılım kısıtlılıklarının incelenmesi için Pediatrik Veri Toplama Aracı (PVTA) kullanıldı. Kanser tanısı almış ve sağlıklı çocukların ve adölesanların katılım düzeyleri arasındaki fark düzeyini karşılaştırmak için Mann-Whitney U testi kullanıldı. Kanser tanısına göre katılım düzeylerini karşılaştırmak için ise Kruskal Wallis kullanıldı.

Bulgular: Çalışmaya katılan çocukların %14,5'i akut lenfoblastik lösemi, %21'i lenfoma ve %64,5'i beyin tümörü tanısı almıştı. Kanser tanısı alan ve sağlıklı adölesanlar arasında PVTA testinin tüm alt parametreleri arasında anlamlı fark bulundu (p=0,001). Kanser türlerine göre global fonksiyon ve rahatlık (p=0,020), üst ekstremite fonksiyonu(p=0,001) ve fiziksel fonksiyon/spor parametreleri arasında anlamlı fark bulundu (p=0,006) özellikle beyin tümörü tanılı çocukların en fazla fonksiyonel sınırlılığa sahip olduğu bulundu. Transfer & mobilite(p=0,847), rahatlık /ağrısızlık (p=0,020) ve mutluluk & memnuniyet (p=0,061) parametrelerinde anlamlı fark bulunamadı.

Sonuç: Kanser tanısı alan çocuklarda tanı ve tedavi süreçlerine bağlı olarak uzun dönemde katılım kısıtlılıkları ortaya çıkmaktadır. Bu kısıtlılıklar özellikle fiziksel boyutta olmakla birlikte kanserin türüne göre değişkenlik göstermektedir. Bu süreçte çocukların ve adölesanların katılım kısıtlılıkları ve ilişkili nedenler detaylıca inceleyen ileri çalışmalar önerilmektedir.

Anahtar kelimeler: Adölesan, Çocuk, Kanser, Katılım, hasta.

Abstract

Purpose: *This descriptive study aimed to examine participation restrictions affecting activity performance in children and adolescents diagnosed with cancer.*

Methods: *The study included 62 children and adolescents diagnosed with cancer who had been receiving treatment for more than one year (mean age: 10.07±3.83 years) and 54 healthy children and adolescents (mean age: 9.29±3.43 years). The Pediatric Outcomes Data Collection Instrument (PODCI) was used to assess participation limitations. The PODCI consists of five main subdomains related to participation in daily living activities.The Mann-Whitney U test was used to compare participation levels between children and adolescents with cancer and their healthy counterparts, while the Kruskal-Wallis test was applied to compare participation levels among different cancer diagnoses.*

Results: *Of the children participating in the study, 14.5% were diagnosed with acute lymphoblastic leukemia, 21% with lymphoma, and 64.5% with brain tumors. A significant difference was found between adolescents diagnosed with cancer and healthy adolescents in all subparameters of the PVTA test (p=0.001). There were significant differences among cancer types in global function and comfort (p=0.020), upper extremity function (p=0.001), and physical function/sports (p=0.006). However, no significant differences were found in transfer and mobility (p=0.847), pain/comfort (p=0.020), or happiness and satisfaction (p=0.061).*

Conclusion: *Children diagnosed with cancer experience long-term participation restrictions due to their diagnosis and treatment processes. These restrictions are primarily physical but vary depending on the type of cancer. Further studies are recommended to explore participation restrictions and their underlying causes in more detail in children and adolescents with cancer.*

Keywords: *Adolescent, Child, Cancer, Participation, patient.*

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GİRİŞ

Kanser, gelişmiş ülkelerde çocuklarda ikinci en yaygın ölüm nedeni olarak tanımlanmıştır.[1] Son yıllarda özel teşhis yöntemlerinin ve kapsamlı tedavi stratejilerinin kullanılması ve sürekli olarak geliştirilmesi, tedavi şansında belirgin bir artış sağlamıştır.[2,3] Sağkalım oranları yüksek olmasına karşın kanser tanısı almış çocuklar kardiyovasküler risk,[4,5] nörolojik,[6] kas-iskelet sistemi[7] ve akciğer komplikasyonları[8] gibi geç etkilerle karşı karşıya kalmaktadır. Hayatta kalanların sayısının artması, pediatrik onkoloji araştırmalarının odağını, bu hastalığın ve tedavisinin hayatta kalanların sağlıkla ilgili yaşam kalitesi üzerindeki uzun vadeli etkilerine doğru kaydırmıştır.[9] Çoğunlukla tedavi tamamlandıktan sonra ortaya çıkan ve sıklıkla tedavilerin kendisinden kaynaklandıkları için "geç etkiler" olarak bilinen bu uzun vadeli etkilerin etkisi geniş çapta araştırılmamıştır.[10] Kanserin geç etkileri arasında katılım kısıtlılıkları da ortaya çıkabilmektedir.[11]

İşlevsellik, Yeti yitimi ve Sağlığın Uluslararası Sınıflandırması (ICF)'na göre Dünya Sağlık Örgütü, katılımı yaşam durumuna katılım olarak tanımlamaktadır. ICF terimlerinde katılımın iki boyutu olduğu tanımlanmaktadır: Bunlar bir aktivite sırasında "orada olmak" ve aktiviteye "dahil olmak"tır. Yaşam durumlarına katılım, çocukların kişilerarası, sosyal ve fiziksel çevreleriyle etkileşimlerinde gerçekleşir.[12,13] Amaca yönelik aktivitelere katılım, çocuğun güven kazanmasını, becerilerini geliştirmesini ve yeterlilik duygusu yaratmasına fırsat sağlamaktadır.[14] Kanserli çocuklarda katılım kısıtlılıkları, hastalığın ve tedavinin etkileri nedeniyle çocukların çeşitli günlük yaşam aktivitelerine ve sosyal faaliyetlere katılma becerilerini engelleyen kısıtlama veya engelleri ifade etmektedir.[15-17] Bu kısıtlamalar çocuğun yaşamının fiziksel,[18] duygusal[19] ve sosyal[20] alanları da dahil olmak üzere farklı boyutlarda ortaya çıkabilir. Fiziksel sınırlamalar kanser tedavisinin yorgunluk, halsizlik, ağrı ve hareket yeteneklerinin azalması gibi yan etkileri, çocuğun fiziksel aktivitelere, oyunlara ve kişisel bakım görevlerine katılma yeteneğini kısıtlayabilir.[21] Kanser tanısı almış çocuklar, teşhis, tedavi prosedürleri ve geleceğe ilişkin belirsizlik nedeniyle duygusal sıkıntı, kaygı, depresyon ve korku yaşayabilir. Bu duygusal zorluklar motivasyonlarını, güvenlerini ve aktivitelere katılma isteklerini etkileyebilir 19. Uzun süreli hastanede kalışlar, sık tıbbi randevular ve zayıflamış bağışıklık sistemleri, sosyal izolasyona ve akranlardan, arkadaşlardan ve okuldan ayrılmaya yol açabilir.[22] Kanserli çocuklar sosyal ağlardan kopuk hissedebilir, ilişkilerini sürdürmek ve sosyal etkinliklere katılmakta zorluk yaşayabilirler. Kanser tedavisi, sık sık okula devamsızlığa, konsantrasyon güçlüğüne, bilişsel bozukluklara ve öğrenme güçlüklerine neden olarak çocuğun eğitimini aksatabilir. Akademik zorluklar sınıf aktivitelerine, eğitim fırsatlarına ve ders dışı aktivitelere katılımlarını sınırlayabilir.[23,24]

Kanserli çocuklarda katılım kısıtlamalarının ele alınması, onların fiziksel, duygusal ve sosyal ihtiyaçlarını dikkate alan kapsamlı bir yaklaşım gerektirir.[25,26] Bu tanımlayıcı çalışma kanser tanısı almış çocuk ve adölesanlarda katılımın farklı boyutlarını ve katılım kısıtlılıklarını tanımlamayı amaçlamaktadır. Araştırmanın temel hipotezleri şunlardır: Kanser tanısı almış çocuk ve adölesanlar ile sağlıklı akranları arasında katılımın farklı boyutlarında ve katılım kısıtlılıklarında istatistiksel olarak anlamlı bir fark yoktur. Kanser türüne göre katılımın farklı boyutlarında ve katılım kısıtlılıklarında istatistiksel olarak anlamlı bir fark yoktur.

YÖNTEM

Çalışma tasarımı ve katılımcılar

Bu kesitsel çalışmaya, kanser tanısı almış ve bir yıldan uzun süredir tedavi gören 3-18 yaş arası çocuklar ve onların sağlıklı kardeşleri dahil edildi. Çalışmaya katılan kanser tanılı çocuk ve adölesanlar için dahil edilme kriterleri şunlardı: bir yıldan uzun süredir kanser tedavisi alıyor olmak, palyatif bakım sürecinde olmamak ve 3-18 yaş aralığında olmak. Çocukların ve adölesanların katılım düzeylerini ciddi derecede etkileyecek kardiyovasküler (n=2), pulmoner (n=1), kognitif (n=3), nörolojik(n=1) veya lokomotor (n=4) sistemlerinde ciddi bozuklukları olması durumunda çalışmadan çıkarıldı. Sağlıklı kardeşler için ise benzer şekilde katılım düzeylerini etkileyebilecek ciddi hastalık

(psikiyatrik, ortopedik, nörolojik vb. veya engel tanısına sahip olmak dışlanma kriteriydi. Katılımcıların 3-10 yaş grubu arasında olanları çocuk, 11-18 yaş grubunda olanları adölesan olarak gruplandırıldı.

Değerlendirme araçları

Demografik Form: Kanser tanısı almış çocukların yaş, cinsiyet, kanser alt tipi, tedavi durumu hastane kayıtlarından elde edildi. Sağlıklı çocuklara ait yaş, cinsiyet, kardeş sayısı gibi veriler oluşturulan demografik formla kaydedildi. Çocukların medikal durumları hakkında bilgilere hasta kayıtları ve hekimlerinden ulaşıldı.

Pediatrik Veri Toplama Aracı (PVTA): Çocuklar ve adölesanların katılım kısıtlılıklarını değerlendirmek için kullanıldı.[27] PVTA üst ekstremite fonksiyonları, transfer ve temel mobilite, spor ve fiziksel fonksiyon, ağrı/rahatlık ve mutluluğu kapsayan günlük yaşam aktivitelerine katılımla ilgili 5 ana alt bölümden oluşmaktadır. Puanlar 0 ile 100 puan arasında değişmekte olup, yüksek puanlar daha iyi katılım düzeyini göstermektedir. Çocuklarda değerlendirilen puanların yaş ve cinsiyet uyumlu normatife göre yüzdesi hesaplandı. PVTA, farklı tanıları olan çocuklarda aktivite ve katılım sınırlamalarını belirlemek için iyi bir güvenilirliğe ve geçerliliğe sahiptir. PVTA'nın Türkçe versiyonunun iç tutarlılığı kabul edilebilir düzeyde ve test-tekrar test güvenilirliği oldukça yüksek bulunmuştur (Alfa=0.93, ICC=0.992).[28-30] Katılımcının yaşına göre PVTA anketi iki şekilde uygulandı. 2 ila 10 yaş arası çocuklar için anket ebeveynleri tarafından doldurduldu. 11 ila 18 yaş arasındaki adölesanlar anketi bağımsız olarak doldurdu.

İstatistiksel analiz

İstatistiksel analizler SPSS versiyon 23.0 kullanılarak yapıldı. Tüm istatistiksel analizler için anlamlılık düzeyi 0,05 olarak belirlendi ve sonuçlar yüzde (%) veya ortalama ± standart sapma olarak ifade edildi. Dağılımın normalliğini belirlemek için Kolmogorov-Smirnov testi kullanıldı. Verilerimiz parametrik varsayımları karşılamadığından kanser tanısı almış ve sağlıklı çocukların katılım düzeyleri, adölesan ve çocukların katılım düzeyleri arasındaki fark düzeyini karşılaştırmak için Mann-Whitney U testi kullanıldı. Kanser tanısına göre katılım düzeylerini karşılaştırmak için ise Kruskal Wallis testi kullanıldı.

Araştırmanın etik yönü

Çalışma protokolü Bezmialem Vakıf Üniversitesi Kurumsal Etik Kurulu tarafından onaylandı (E-54022451-050.05.04-43888/ 14.12.2021). Bu araştırmada sadece araştırmaya katılmaya gönüllü olan katılımcılardan veri toplanmıştır. Katılımcılara araştırmanın amacı ve önemi açıklanmış ve araştırmaya katılım için onayları alınmıştır. Araştırma yürütülürken Helsinki Deklarasyonu Prensipleri'ne bağlı kalınmıştır.

BULGULAR

Çalışmaya 30 kanser tanılı çocuk, 32 kanser tanılı adölesan, 24 sağlıklı çocuk ve 30 sağlıklı adölesan katıldı. Kanser tanılı çocuk ve adölesanların ortalama tedavi süresi 20±4,3 aydı ve katılımcıların %75,8'i aynı anda birden fazla tedavi almaktaydı. Kanser tanılı çocuk ve adolesanlara ait tanımlayıcı veriler Tablo 1'de gösterildi.

Kanser tanısı almış çocuklar ve sağlıklı çocuklar arasında PVTA testinin tüm alt parametreleri arasında anlamlı fark bulundu

Tablo 1. Kanser tanılı çocuklar ve adölesanların sosyodemografik özellikleri (N=62).

	X±SD
Yaş (yıl)	10,1±3,8
Tedavi süresi (Ay)	20,0±4,3
	n (%)
Cinsiyet	
Kız	26 (42)
Erkek	36 (58)
Kanser alt türleri	
Akut lenfoblastik lösemi	9 (14,5)
Lenfoma	13 (21)
Beyin tümörü	40 (64,5)
Tedavi	
Kemoterapi	12 (19,3)
Cerrahi	3 (4,8)
Kemoterapi + radyoterapi	14 (22,5)
Kemoterapi + cerrahi	3 (4,8)
Radyoterapi + cerrahi	2 (3,2)
Kemoterapi + radyoterapi + cerrahi	28 (45,1)

(p<0,05). Kanser tanısı almış adölesanlar ve sağlıklı adölesanlar arasında da PVTA testinin tüm alt parametreleri arasında anlamlı fark bulundu (p<0,05) (Tablo 2 ve Tablo 3).

Kanser türlerine göre global fonksiyon ve rahatlık, üst ekstremite fonksiyonu ve fiziksel fonksiyon/spor parametreleri arasında anlamlı fark bulundu (p<0,05). Global Fonksiyon & Rahatlık alt testinde ALL tanılı çocuklar ($\bar{X}$ = 45,11) en yüksek skoru alırken, NHL tanılı çocuklar ($\bar{X}$ = 35,15) ve BT tanılı çocuklar ($\bar{X}$ = 27,25) daha düşük skorlar almıştır. Gruplar arasındaki fark istatistiksel olarak anlamlıdır (χ^2 = 7,796, p = 0,02), bu da kanser türüne göre genel fonksiyon ve rahatlık düzeyinde farklılık olduğunu göstermektedir. Üst Ekstremite Fonksiyonu alt testinde ALL ve NHL tanılı çocukların skorları birbirine yakın ($\bar{X}$ = 43,83 ve $\bar{X}$ = 44,08), ancak BT tanılı çocukların skoru anlamlı derecede düşüktür ($\bar{X}$ = 24,64). Fark oldukça belirgin ve istatistiksel olarak anlamlıdır (χ^2 = 16,868, p = 0,001). Bu sonuç, beyin tümörü tanılı çocukların üst ekstremite fonksiyonlarının diğer gruplara kıyasla belirgin şekilde daha fazla etkilendiğini göstermektedir. Fiziksel Fonksiyon & Spor alt testinde ALL tanılı çocuklar ($\bar{X}$ = 43,39) en yüksek skoru alırken, NHL tanılı çocuklar ($\bar{X}$ = 37,54) ve BT tanılı çocuklar ($\bar{X}$ = 26,86) daha düşük skorlar almıştır. Fark istatistiksel olarak anlamlıdır (χ^2 = 10,147, p = 0,006). Transfer & mobilite, rahatlık /ağrısızlık ve mutluluk & memnuniyet parametrelerinde ise anlamlı fark bulunamadı (Tablo 4).

TARTIŞMA

Kanser türlerine göre global fonksiyon ve rahatlık, üst ekstremite fonksiyonu ve fiziksel fonksiyon/spor parametreleri arasında beyin tümörlü çocuk ve adölesanların daha düşük katılım seviyesinde olduğu bulundu. Özellikle spor ve fiziksel fonksiyon ile günlük yaşam aktivitelerine katılımda ağrı/rahatlık skorlarının PVTA' nın diğer alt başlıklarına göre daha fazla etkilendiği belirlendi.

ALL tanılı çocuklar global fonksiyon ve rahatlıkta en yüksek skoru alırken, BT tanılı çocuklar en düşük skoru almıştır. Kyung ve ark. (2018), beyin tümörü tanılı çocukların fiziksel sağlık, duygusal işlevsellik, sosyal işlevsellik ve okul katılımı açısından sağlıklı akranlarına göre daha düşük seviyelerde olduğunu bildirmiştir.[31] Bu bulgu, beyin tümörlerinin çocuklarda genel fonksiyonel kapasiteyi belirgin şekilde düşürdüğünü ve günlük yaşam aktivitelerine katılımı daha fazla sınırladığını göstermektedir. Bu bulgu, beyin tümörlerinin çocukların fonksiyonel kapasitelerini diğer kanser türlerine göre daha fazla etkilenmiş olabileceğini, kanser tanısının ve türünün katılım düzeyleri üzerinde belirleyici bir faktör olabileceğini düşündürmektedir.

Üst ekstremite fonksiyonlarında, ALL ve NHL tanılı çocukların skorları benzer bulunurken, BT tanılı çocuklar anlamlı derecede daha düşük skor almıştır. Bu sonuç, beyin tümörünün santral sinir sistemine etkisi nedeniyle ince ve kaba motor becerileri olumsuz etkilediğini düşündürmektedir. Beyin tümörü tanısı almış çocukların üst ekstremite koordinasyonu ve el becerilerinde belirgin zorluklar yaşadığını ve bunun günlük yaşam aktivitelerine katılımı olumsuz etkilediğini çeşitli çalışmalarda raporlanmıştır.[32-34] Tümörün konumu ve büyüklüğü, motor korteks ve ilgili sinir yollarını etkileyerek motor fonksiyonlarda bozulmalara yol açabilir.

ALL tanılı çocuklar fiziksel fonksiyon ve spor alt testinde en yüksek skoru alırken, NHL tanılı çocuklar ve BT tanılı çocuklar daha düşük skorlar almıştır. Bu sonuç, BT tanılı çocukların fiziksel aktiviteye katılımının sınırlı olduğunu ve günlük yaşam aktivitelerinde daha fazla fonksiyon kaybı yaşadığını göstermektedir. Beyin tümörü tedavisinin çocuklarda kas gücü kaybı, denge problemleri ve azalmış egzersiz toleransı ile ilişkili olduğunu bildirmiştir.[35] Diğer bir çalışma beyin tümörüne sahip çocukların hem motor hem de süreç becerilerinde önemli kısıtlamalar tespit etmiş ve bu durumun günlük yaşam aktivitelerindeki performanslarını etkilediğini raporlamıştır.[36]

Çalışmada transfer & mobilite, rahatlık/ağrısızlık ve mutluluk/memnuniyet parametrelerinde kanser türleri arasında anlamlı fark bulunmamıştır (p > 0.05). Bu durum, kanser türünden bağımsız olarak tüm kanser tanılı çocukların belirli düzeyde mobilite ve konfor kısıtlılıkları yaşadığını düşündürmektedir. Barbosa ve ark. çocukluk çağı kanserleri sonrasında mobilite kaybının yaygın olduğunu ve tümör tipinden bağımsız olarak fiziksel aktivite düzeyinin azaldığını bildirmiştir.[37] Özellikle ağrı ve rahatlık

Tablo 2. Kanser tanılı çocuklar ve sağlıklı çocukların katılım düzeylerinin karşılaştırılması.

	Kanser Tanılı (N=30)	Sağlıklı (N=24)	
	X±SD	X±SD	p
Global fonksiyon ve rahatlık	33,52±3,16	87,19±2,13	<0,001
Üst ekstremite fonksiyonu	36,29±8,23	84,00±5,26	<0,001
Fiziksel fonksiyon ve spor	34,98±9,12	85,50±6,56	<0,001
Transfer ve mobilite	43,35±8,13	75,89±4,36	<0,001
Rahatlık / ağrısızlık	30,16±11,16	79,56±3,07	<0,001
Mutluluk ve memnuniyet	36,31±8,16	82,50±4,26	<0,001

Tablo 3. Kanser tanılı adölesanlar ve sağlıklı adölesanlar katılım düzeylerinin karşılaştırılması.

	Kanser Tanılı (N=32)	Sağlıklı (N=30)	
	X±SD	X±SD	p
Global fonksiyon ve rahatlık	35,52±4,12	88,30±3,01	<0,001
Üst ekstremite fonksiyonu	37,28±9,14	89,00±2,16	<0,001
Fiziksel fonksiyon ve spor	38,98±8,56	88,50±1,14	<0,001
Transfer ve mobilite	46,35±9,86	75,88±4,76	<0,001
Rahatlık / ağrısızlık	33,15±10,12	82,29±2,36	<0,001
Mutluluk ve memnuniyet	38,44±6,34	86,90±3,45	<0,001

Tablo 4. Kanser türlerine göre katılım düzeylerinin karşılaştırılması.

	ALL (n=9)	NHL (n=13)	BT (n=40)	
	X±SD	X±SD	X±SD	p
Global fonksiyon ve rahatlık	45,1±8,5	35,2±6,9	27,3±7,1	0,020*
Üst ekstremite fonksiyonu	43,8±7,8	44,1±7,2	24,6±6,5	0,001*
Fiziksel fonksiyon ve spor	43,4±9,1	37,5±8,7	26,9±7,9	0,006*
Transfer ve mobilite	34,8±8,3	33,9±7,5	30,0±7,0	0,847
Rahatlık / ağrısızlık	42,0±7,9	27,7±6,8	30,4±6,4	0,300
PVTA Mutluluk ve memnuniyet	42,5±8,0	34,2±7,6	27,3±7,2	0,061

* p<0,05. PVTA: Pediatrik Veri Toplama Aracı. ALL: Akut Lenfoblastik Lösemi. NHL: Non Hodgin Lenfoma. BT: Beyin Tümörü.

düzeyleri açısından anlamlı fark bulunmaması, kanser türünden bağımsız olarak tedavi sürecinin çocuklarda ağrı ve rahatsızlık yaratan yaygın etkilerinin olduğunu düşündürmektedir. 2.836 kanserden sağ kalan bireyin yer aldığı çalışmada, katılımcıların %18'i orta ila çok şiddetli ağrı ve orta ila aşırı düzeyde günlük yaşam etkilenimi bildirmiştir. Ayrıca, şiddetli ve yaşamı tehdit eden kronik sağlık koşulları, ağrının günlük yaşam üzerindeki etkisinin artmasıyla ilişkilendirilmiştir.[38]

Bu çalışmada, kanser tanısı almış çocuklar

ve adölesanlar ile sağlıklı kardeşleri arasında PVTA testinin tüm alt parametrelerinde anlamlı farklar bulunduğu belirlenmiştir. Çocukluk çağı kanserleri ve bunlara bağlı tedavi süreçleri, nörolojik, kas-iskelet sistemi, metabolik ve psikososyal birçok değişkeni etkileyerek çocukların fonksiyonel kapasitelerini düşürebilir. Kemoterapi, radyoterapi ve cerrahi müdahaleler, çocukların motor becerilerini, dayanıklılığını ve genel fiziksel uygunluğunu olumsuz etkileyebilir. Özellikle, uzun süreli yorgunluk, kas gücü kaybı, periferik nöropati ve kardiyovasküler komplikasyonlar, çocukların günlük yaşam aktivitelerine katılımını kısıtlayan temel etmenler arasında yer alabilir. Götte ve ark.[39] çocukluk çağı kanserlerinden sağ kalan bireylerin motor performanslarının sağlıklı akranlarına kıyasla anlamlı şekilde düşük olduğunu ve fiziksel aktivitelere katılımda zorluk yaşadıklarını bildirmiştir. Ayrıca, kanser tanısı almış çocukların, sağlıklı akranlarına kıyasla ağrı ve yorgunluk gibi semptomları daha yoğun yaşadığı, bunun da fonksiyonel kapasitelerini olumsuz etkilediği gösterilmiştir. Braam ve ark. (2019), çocukluk çağı kanserlerinden sağ kalan bireylerin sağlıklı çocuklara kıyasla daha düşük kardiyorespiratuar dayanıklılığa sahip olduğunu ve bu durumun uzun vadede fiziksel aktivite seviyelerini düşürdüğünü göstermiştir.[40] Götte et al. (2017) ise kanser tanılı çocuklarda egzersiz kapasitesinin ve fiziksel aktivite seviyelerinin sağlıklı yaşıtlarına kıyasla belirgin şekilde düşük olduğunu belirtmiştir. Bu bulgumuzdan yola çıkarak, kanserin çocukların günlük yaşam aktivitelerine katılımı üzerinde geniş kapsamlı ve çok yönlü etkileri olduğunu gösterdiği düşünülebilir.

Limitasyonlar

Araştırmanın bazı sınırlılıkları mevcuttur. Çalışmada en sık karşılaşılan çocukluk kanserlerinden olan beyin tümörü, lösemi ve lenfomalı çocuklar dahil edilmiş olsa da farklı kanser tanısına sahip çocukların katılım düzeylerinin nasıl etkilendiğinin tanımlanması çalışma kalitesinin geliştirilmesi açısından etkili olabilirdi. Verilerin normal dağılım göstermemesi sebebiyle non-parametrik yöntemlerin kullanılmıştır. Gelecekteki çalışmalara daha büyük örneklem büyüklüğü ile kanserli çocuklarda katılımı etkileyen parametreleri araştırabilir.

Sonuç

Bu çalışma, kanser tanısı almış çocuk ve adölesanların sağlıklı akranlarına kıyasla günlük yaşam aktivitelerine katılım düzeylerinde belirgin kısıtlılıklar yaşadığını ve bu kısıtlılıkların kanser türüne bağlı olarak farklılık gösterdiğini ortaya koymaktadır. Beyin tümörü (BT) tanılı çocukların özellikle üst ekstremite fonksiyonları, fiziksel fonksiyon/spor aktiviteleri ve genel fonksiyonel rahatlık açısından daha fazla etkilendiği belirlenmiştir. Bununla birlikte, tüm kanser türleri mobilite, ağrı ve genel mutluluk/memnuniyet düzeylerini olumsuz etkilemiştir. Kanser tanılı çocukların ve adölesanların katılım kısıtlılıkları ve ilişkili nedenlerin detaylıca incelendiği ileri çalışmalar önerilmektedir.

Teşekkür: *Çalışmaya katılmayı kabul eden tüm çocuklar ve ailelerine teşekkür ederiz.*

Yazarların Katkı Beyanı: GGY: Fikir kavram, tasarım ve dizayn, kaynaklar, veri toplama ve işleme, analiz ve yorum, literatür taraması, eleştirel inceleme ve yazım; **MT:** Fikir kavram, tasarım ve dizayn, kaynaklar, veri toplama ve işleme, analiz ve yorum, literatür taraması, eleştirel inceleme ve yazım; **SŞ:** Fikir kavram, tasarım ve dizayn, kaynaklar, veri toplama ve işleme, analiz ve yorum, literatür taraması, eleştirel inceleme ve yazım; **FBÇ:** Denetleme/danışmanlık, malzemeler, veri toplama ve işleme ve eleştirel inceleme

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ORIGINAL ARTICLE

Comparative analysis of foot biomechanical characteristics in adolescent football and handball players and sedentary individuals: a retrospective study

Adölesan futbol ve hentbol oyuncularında ayak biyomekanik özelliklerinin sedanter bireylerle karşılaştırılması: retrospektif çalışma

Büşra SEZER[1], Şulenur YILDIZ[1]

Abstract

Purpose: Foot structure during adolescence may vary due to growth-related changes and differences in physical activity levels. However, evidence regarding the impact of regular sports participation on foot biomechanics remains limited. This study aimed to retrospectively compare foot biomechanical characteristics between adolescents with and without regular sports participation.
Methods: Sixty healthy adolescents aged 10–18 years were classified into a sports-active group (n=30) and a non-sports group (n=30). Foot biomechanics were assessed using the Staheli Index (SI) obtained from ink footprint analysis, the Foot Posture Index (FPI), and the hallux valgus (HV) angle.
Results: A statistically significant difference in age was observed between the groups (p=0.049); however, adjustment for age did not alter the main findings. The sports-active group demonstrated significantly lower Foot Posture Index scores for both feet (p=0.005 and p=0.003) and lower Staheli Index values (p=0.003 and p=0.001). Group differences in Foot Postur Index remained significant after age adjustment (right: p=0.024; left: p=0.019). No significant differences were detected in Hallux Valgus angles (p > 0.05).
Conclusions: Adolescents who participate in sports regularly exhibit a more neutral foot posture and better preservation of the medial longitudinal arch. These findings support a potentially beneficial role of organized sports in adolescent foot development, provide a foundation for future research, and underscore the need for well-designed longitudinal studies to clarify causality.
Keywords: Sports, Posture, Foot deformities, Adolescent.

Öz

Amaç: *Ergenlik döneminde ayak yapısı, büyüme ile ilişkili değişiklikler ve fiziksel aktivite düzeylerindeki farklılıklara bağlı olarak değişiklik gösterebilir. Ancak düzenli spor yapmanın ayak biyomekaniği üzerindeki etkisine dair kanıtlar sınırlıdır. Bu çalışma, spor yapma alışkanlığı olan ve olmayan ergenlerin ayak biyomekanik özelliklerini retrospektif karşılaştırmayı amaçlamıştır.*
Yöntem: *10–18 yaş arası 60 sağlıklı ergen, spor yapan grup (n=30) ve spor yapmayan grup (n=30) olarak sınıflandırılmıştır. Ayak biyomekaniği, mürekkep taban izi analizi ile elde edilen Staheli İndeksi (Sİ), Ayak Postür İndeksi (APİ) ve halluks valgus (HV) açısı kullanılarak değerlendirilmiştir.*
Bulgular: *Gruplar arasında yaş açısından istatistiksel olarak anlamlı bir fark bulunmuştur (p=0,049); ancak yaş farkı dikkate alınarak yapılan düzeltme sonrasında temel bulgular değişmemiş ve grup farklılıkları hâlâ anlamlıdır. Spor yapan grup, her iki ayakta da ayak postür indeksi skorları açısından anlamlı şekilde daha düşük değerler göstermiştir (p=0,005 ve p=0,003) ve Staheli İndeksi değerleri daha düşük bulunmuştur (p=0,003 ve p=0,001). Yaşa göre yapılan düzeltme sonrasında Ayak postür indeksi'ndeki grup farkları anlamlılığını korumuştur (sağ: p=0,024; sol: p=0,019). Halluks valgus açılarında ise anlamlı bir fark bulunmamıştır (p > 0,05).*
Sonuçlar: *Düzenli olarak spor yapan ergenlerde ayak postürü daha nötral olup, medial longitudinal ark daha iyi korunmaktadır. Bu bulgular, organize sporların ergenlik döneminde ayak gelişimi üzerinde potansiyel olarak yararlı bir rolü olabileceğini desteklemekte, gelecekte yapılacak araştırmalar için bir temel sunmakta ve nedenselliğin açıklığa kavuşturulması amacıyla iyi tasarlanmış uzunlamasına çalışmalara duyulan ihtiyacın önemini vurgulamaktadır.*
Anahtar kelimeler: *Spor, Postür, Ayak deformiteleri, Adölesan.*

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INTRODUCTION

Adolescence represents a developmental phase marked by rapid skeletal and muscular growth, which is associated with biomechanical changes in the body's center of mass and the forces produced during movement.[1,2] Although the World Health Organization defines adolescence as the chronological age range of 10–19 years, the timing and rate of development of bodily structures differ within this period.[3] When foot development is considered, complete ossification of the foot bones is known to occur within the first decade of life, and following the ossification process and closure of the epiphyseal plates, the feet typically attain adult dimensions between the ages of 15 and 21.[4]

Feet that exhibit pronation in childhood progressively adopt their definitive posture as maturation occurs. Throughout this developmental process, both intrinsic and extrinsic factors play a role in shaping foot development and foot posture.[5] Foot development is an important marker of the body's developmental process, with maximal increases in foot length occurring early in puberty, before peak height growth.[6,7] Foot biomechanics, which completes its development toward the end of adolescence, plays a critical role in both daily functional activities and sports participation.[8] Engagement in regular physical activity or sports at an early age may represent one of the most influential extrinsic factors affecting foot development.[8] Therefore, adolescence represents a critical period for evaluating foot structure and biomechanics due to rapid growth and ongoing physiological and anatomical changes.[9]

It is important to examine the foot biomechanical characteristics in relation to sports participation, which represents one of the extrinsic factors influencing the development of neuromuscular skills during adolescence. Although the rate of maturation related morphological changes is similar between athletes and non-athletes, evidence suggests that athletes may exhibit a higher rate of adaptation within the muscle tendon system.[10] This finding indicates that sports participation may contribute to the development of motor control in adolescents through adaptations in the muscle–tendon system. The medial longitudinal arch (MLA), which is supported by this system, plays a key role in load transfer, shock absorption, and lower-extremity alignment. Accordingly, sports participation during adolescence may exert significant effects on foot biomechanical properties via the MLA. Therefore, comparative investigation of adolescents with and without sports participation is warranted. Among the measurements commonly used to assess foot posture and arch morphology in clinical and research settings are the Foot Posture Index (FPI-6) and the Staheli Index (SI), calculated from footprint analysis.[11,12] However, studies directly comparing adolescents with and without regular exercise habits using standardized measures such as the FPI-6 and Staheli Index have not been found; the existing literature generally examines younger age groups or uses only a single measurement method.[12-15] Additionally, identifying the parameters that may have potential effects on normal foot development during adolescence facilitates understanding of important risk factors related to any misalignment of the foot and other functional disorders.[16]

This study aimed to address the lack of evidence regarding the comprehensive assessment of foot biomechanical characteristics in adolescents using standardized criteria, taking into account the natural variability of foot posture during the developmental period and the possible modifying effects of participation in sports. In this context, the primary objective of this study is to compare the foot biomechanical characteristics of adolescent football and handball players with those of sedentary adolescents in a retrospective design. By providing detailed comparisons between athletes in specific sports and sedentary peers, this study aims to contribute to the literature by clarifying how organized sports participation may influence foot structure and posture during adolescence, offering insights for clinicians and researchers interested in adolescent foot biomechanics and injury prevention.

METHODS

Retrospective observational study

Adolescents who were evaluated at at the Physical Therapy and Rehabilitation Clinics, Hacettepe University, Turkey between June

2024 and January 2025 were retrospectively reviewed in this observational study.

Participants

The study included data from healthy adolescents aged 10–18 years who participated on a voluntary basis. Individuals with diagnosed orthopedic, neurological, or rheumatologic conditions; a history of lower extremity trauma or surgery; or a body mass index exceeding 30 kg/m² were excluded. Participants in the sports group were adolescent football and handball players who had participated in structured training sessions 2–3 times per week for at least one year; they were not professional athletes. The control group consisted of sedentary adolescents who did not engage in any regular sports or physical activity but attended school and carried out routine daily activities.

Procedure

An a priori power analysis was conducted using G*Power (version 3.1.9.7) for a two-tailed independent samples t-test (α=0.05, power=0.80). Based on pilot data obtained from 20 participants per group, the effect size calculated for the right Foot Posture Index (FPI) score was Cohen's d=1.06. The analysis indicated that a minimum of 15 participants per group was required. To enhance the robustness and precision of the findings, 30 adolescents were included in each group (total n=60). The Staheli Index, Foot Posture Index (FPI-6), and hallux valgus angle were predefined as the primary outcome measures. Demographic characteristics, including age, sex, height, and body weight were extracted from the assessment records.

Measures

Data related to foot biomechanics were retrospectively obtained from the participants' assessment forms, including the following evaluations.

Foot posture was assessed using the Foot Posture Index (FPI).[11] The Foot Posture Index (FPI) is a six-item clinical tool designed to assess foot posture in multiple planes, classifying it as pronated, neutral, or supinated. The assessment items include palpation of the talar head, inspection of the curves above and below the lateral malleolus, calcaneal inversion/eversion, prominence of the talonavicular joint, medial longitudinal arch configuration, and forefoot abduction/adduction relative to the hindfoot. Each item is scored on a scale from -2 to +2, producing a total score between -12 and +12. Total FPI scores of 0 to +5 indicate normal foot posture, +6 to +9 indicate pronation, +10 to +12 indicate excessive pronation, -1 to -4 indicate supination, and -5 to -12 indicate excessive supination. In this evaluation, the right and left feet are assessed separately while the participant is in a standing position.

The Harris Mat was used to assess participants' medial longitudinal arches. The Staheli Index (SI) is a footprint-based metric used to quantify the height of the medial longitudinal arch and is commonly applied to identify flatfoot or high-arched feet. The SI was calculated as the ratio of the narrowest portion of the midfoot to the widest portion of the hindfoot, based on footprints obtained from an inked surface. Arch classification was defined as high (pes cavus) for ratios $\leq$ 0.4, normal for ratios between 0.5 and 0.7, and low (pes planus) for ratios $\geq$ 0.8.[12]

The hallux valgus (HV) angle, defined as the angle between the longitudinal axes of the first metatarsal and the proximal phalanx, is used to evaluate the severity of hallux valgus deformity. Bilateral measurements were performed using a universal goniometer, with angles greater than 15° considered indicative of HV.[17]

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics version 23.0 (IBM Corp., Armonk, NY, USA).[18] Data distribution was assessed using skewness and kurtosis values. Continuous variables were expressed as median (interquartile range) due to non-normal distribution. Categorical variables were presented as frequencies and percentages. Between-group comparisons were conducted using the Mann–Whitney U test. Spearman correlation analysis was used to evaluate associations between age and foot parameters. ANCOVA was performed for FPI to control for age differences between groups, with effect sizes reported as partial eta squared (η^2). A two-tailed p-value <0.05 was considered statistically significant.

RESULTS

A total of 60 adolescents were included in the analysis. The demographic and physical

characteristics of the participants are presented in Table 1. Group 1 (adolescent football and handball players, n=30) and Group 2 (sedentary adolescents, n=30) were compared. The median age was 14 (IQR: 3) years in Group 1 and 12 (IQR: 4) years in Group 2, with a statistically significant difference between groups (p=0.049). No significant differences were observed between the groups in body mass index or sex distribution.

Table 1. Demographic and physical characteristics of adolescents.

	Group 1 (N=30)	Group 2 (N=30)	
	Median (IQR)	Median (IQR)	p
Age (years)	14 (3)	12 (4)	0.49
	X±SD	X±SD	
BMI (kg/m²)	19.53±2.08	19.47±3.20	0.93
Gender	n (%)	n (%)	
Female	16 (53)	15 (50)	0.79
Male	14 (47)	15 (50)	

BMI: Body Mass Index. IQR: Interquartile Range. Group 1: Adolescent football and handball players. Group 2: Sedentary adolescents not engaged in regular sports activity.

Table 2. Comparison of foot biomechanics results between groups.

	Group 1 (N=30)	Group 2 (N=30)	
	Median (IQR)	Median (IQR)	p
Foot Posture Index			
Right	2.5 (6.25)	6 (6)	0.005*
Left	3 (6.25)	6 (5.25)	0.003*
Staheli Index			
Right	0.59 (0.18)	0.70 (0.37)	0.003*
Left	0.57 (0.16)	0.69 (0.28)	0.001*
Hallux valgus a. (°)			
Right	8.15 (6)	9 (5)	0.980
Left	8 (5.5)	7.5 (5)	0.970

* p<0.05. a: angle. IQR: Interquartile Range. Group 1: Adolescent football and handball players. Group 2: Sedentary adolescents not engaged in regular sports activity.

Comparisons of foot biomechanical parameters between adolescent football and handball players and sedentary adolescents are presented in Table 2. The Foot Posture Index scores were significantly higher in sedentary adolescents for both feet (right: p=0.005; left: p=0.003). Similarly, Staheli Index values were significantly greater in the sedentary group (right: p=0.003; left: p=0.001). No significant differences were observed in hallux valgus angles ($p > 0.05$).

Spearman correlation analysis revealed a moderate negative association between age and FPI scores for both feet (right: ρ=-0.50, p=0.004; left: ρ=-0.49, p=0.006) (Table 3). No significant correlations were found between age and Staheli Index or hallux valgus angles ($p > 0.05$).

To account for the age difference between groups, an ANCOVA was performed controlling for age (Table 3). After adjustment, group differences in FPI scores remained statistically significant (right FPI: p=0.024, η^2=0.086; left FPI: p=0.019, η^2=0.093). Age was also independently associated with FPI scores (right: p=0.020, η^2=0.091; left: p=0.016, η^2=0.098), indicating moderate effect sizes.

DISCUSSION

This study examined differences in foot biomechanics between adolescents who regularly participated in organized sports (handball and football) and those without regular sports participation. The findings indicate that adolescents with regular sports habits exhibit significantly different foot biomechanical characteristics compared with their non-sporting peers. Lower Foot Posture Index and Staheli Index values observed in the physically active group suggest better maintenance of the medial longitudinal arch with a more optimal level of foot pronation. In this respect, our study is consistent with the literature suggesting that regular exercise and physical activity are associated with positive adaptations in foot biomechanics, including arch structure and postural alignment.[19-22]

As sport is considered a subcategory of physical activity, this finding is further supported by studies examining physical activity levels in relation to foot posture. Previous research comparing adolescents with

Table 3. Age-adjusted analysis and correlation results.

	Spearman ρ (Age)	p	Adjusted p (Group)	Partial η² (Group)	p (Age)	Partial η² (Age)
Foot Posture Index						
Right	-0.50	0.004	0.024	0.086	0.020	0.091
Left	-0.49	0.006	0.019	0.093	0.016	0.098
Staheli Index						
Right	-0.33	0.072				
Left	-0.26	0.16				
Hallux Valgus Angle						
Right	0.188	0.319				
Left	0.217	0.249				

Spearman correlation analysis was used to evaluate associations between age and foot parameters.
ANCOVA was performed only for FPI due to significant age association. Effect sizes are reported as partial eta squared (η²).

and without pes planus reported significantly lower physical activity levels in adolescents with pes planus, suggesting an association between reduced activity and less optimal foot posture.[23] Accordance with this evidence, the present findings suggest that regular participation inorganized sports may contribute to preserving arch structure by counteracting the tendency towards arch flattening. This assumption is supported by studies demonstrating that targeted intrinsic foot muscle training leads to improvements in medial longitudinal arch morphology and function, highlighting the role of repetitive muscular loading in arch support.[20,24] Accordingly, repetitive sport-specific loading may act as an indirect intrinsic muscle training, enhancing muscular support and neuromuscular control of the medial longitudinal arch. In addition, previous research has reported more physiological plantar load distribution in physically active individuals, whereas inactive individuals tend to exhibit greater rearfoot loading, suggesting a potential role of regular mechanical loading in foot biomechanics.[25] Interestingly, a randomized clinical trial comparing short foot exercise with a non-biomechanical function exercise reported no significant between group differences in Foot Posture Index or navicular drop, although both groups demonstrated improvements from baseline.[26] This finding suggests that even nonspecific or low intensity foot related exercises may induce better postural adaptations, potentially through increased neuromuscular activation or general mechanical loading. Similarly, Eldemir et al. (2025) reported greater navicular height in physically active university students, supporting the notion that repeated and structured mechanical loading promotes optimal arch morphology.[27] With all these information, our study supports the association between regular participation in organized sports and favorable foot structural characteristics. However, longitudinal research is still necessary to determine the long-term persistence of these adaptations and their underlying biomechanical mechanisms. In this context, Bukowska et al. (2021) reported that arch length tended to flatten with increasing age in young male athletes undergoing football training. These findings indicate that while sports participation may influence arch characteristics, age-related maturation and sport-specific loading patterns may simultaneously contribute to structural adaptations.[28]

In our study, age also emerged as an important factor. It differed significantly between groups and showed a moderate negative association with FPI scores, consistent with the natural maturation of the medial longitudinal arch during adolescence. After adjusting for age using ANCOVA, group differences in FPI scores remained statistically significant, indicating that these differences cannot be explained solely by age-related development. Together, these findings suggest that although growth and maturation influence foot posture, regular sports participation may exert an additional independent effect.

Despite these favorable findings, evidence regarding the possible effects of sports participation on foot posture remains inconsistent. For example, a study comparing

elite collegiate athletes participating in high-impact sports with sedentary students reported significantly higher Foot Posture Index scores in the athletic group, indicating a greater tendency towards foot pronation despite regular sports participation.[14] Similarly, Spiteri (2024) reported a high prevalence of pronated foot posture among children attending a national sports school.[29] In addition, children participating in artistic and rhythmic gymnastics have been shown to exhibit a tendency toward pronation, characterised by increased hindfoot loading under static conditions.[30] In addition, a posturographic study examining the effects of long-term sports participation reported that athletic training may be associated with subtle alterations in plantar pressure distribution and postural control rather than uniformly favourable adaptations. In that study, athletes exhibited greater asymmetry in foot-loading patterns and increased anteroposterior centre of pressure displacement compared with non-athletes, suggesting sport-specific postural adaptations shaped by training intensity and the specific mechanical demands of the sport.[31] Supporting this interpretation, footprint-based research by Kulthanan et al. demonstrated distinct plantar imprint patterns in athletes compared with non-athletic individuals, indicating that long-term sports participation may influence arch characteristics and plantar loading through mechanical adaptation rather than consistent structural improvement.[32] Collectively, these findings indicate that variations in sport type and training programs may lead to different foot postural adaptations. Supporting this variability, Zhang et al. (2022) highlight that foot morphology is dynamic and adapts to repetitive loading, indicating that sport-specific postural adaptations arise from complex interactions between mechanical demands and individual musculoskeletal characteristics.[33]

In addition to structural and postural adaptations, sport-related foot characteristics may also be reflected in functional performance outcomes. Research conducted in professional football players reported significant associations between Foot Posture Index scores, plantar pressure distribution, and measures of static and dynamic balance, suggesting that long-term sports participation may influence not only foot posture but also postural control strategies.[34] These findings suggest that sport-related foot adaptations in adolescents can be considered not only in terms of isolated structural changes, but also within a broader biomechanical and functional context.

Within this context, the present study adds to the existing evidence by demonstrating that regular participation in organized sports during adolescence is associated with measurable differences in foot biomechanical characteristics. Our findings suggest that athletic adolescents tend to maintain more resilient and optimal arch profiles compared with their sedentary peers, who may lack sufficient repetitive mechanical loading to support arch integrity. However, it should also be considered that foot posture is a multifactorial characteristic influenced not only by current sports participation but also by previous physical activity habits and developmental factors during childhood. Therefore, the observed differences cannot be attributed solely to participation in football and handball.

Overall, these findings suggest that participation in organized sports during adolescence may play a meaningful role in supporting the development of the foot arch and postural alignment, thereby contributing to the existing literature on adolescent foot biomechanics.

Limitations

The findings of this study should be interpreted considering several limitations. First, the inclusion of specific sports branches, namely football and handball, as well as variability in training duration within the sports group, may have affected foot biomechanics outcomes. This may limit the generalizability of the results to other athletic disciplines. Additionally, sports history and training intensity were based on self-reported data, introducing the possibility of recall bias. Furthermore, foot posture may also have been influenced by prior physical activity habits and developmental characteristics during childhood, which were not controlled for in this study.

Future studies including a broader range of sports and adopting longitudinal designs that follow adolescents through skeletal maturation would provide more comprehensive insights into the development of these structural adaptations.

Conclusion

This study demonstrates that regular participation in organized sports during adolescence is associated with a more neutral foot posture and better preservation of the medial longitudinal arch. Our findings suggest that regular sports participation may serve as a protective factor against age-related arch flattening by promoting beneficial biomechanical adaptations during critical growth periods. Although changes in foot structure due to growth are inevitable, structured sports participation appears to support the structural integrity of the developing foot. From a clinical and preventive perspective, encouraging sports participation during adolescence may play an important role in promoting long-term foot health and reducing the risk of biomechanical dysfunction in later life. While these findings suggest a positive association between sports participation and foot health, longitudinal studies are needed to clarify the long-term effects of specific sporting disciplines on foot development and musculoskeletal outcomes.

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ORIGINAL ARTICLE

Comparative analysis of the maximum voluntary isometric contraction of the biceps brachii and triceps brachii at different elbow angles

Farklı dirsek açılarında biceps brachii ve triceps brachii kaslarının maksimum istemli izometrik kasılmasının karşılaştırmalı analizi

Nazlı DÜRÜMLÜ[1], Hasan SÖZEN[2], Sevim ACARÖZ[3]

Abstract

Purpose: The objective of this study is to compare the maximum voluntary isometric contraction (MVIC) values obtained from the biceps brachii (BB) and triceps brachii (TB) muscles at different elbow angles and to determine which angle provides optimum efficiency according to this comparison.
Methods: A total of 30 healthy volunteers participated in the study. Electromyography (EMG) data were obtained at 70°, 90°, and 110° of flexion to measure root mean square (RMS) amplitude during MVIC of BB (for elbow flexion) and TB (for elbow extension) muscles.
Results: For BB, EMG RMS amplitude during MVIC was significantly influenced by elbow joint angle, with the highest activation observed at 70° compared to 90° and 110°. Similarly, TB activation was angle-dependent, showing the greatest values at 70°. The BB/TB EMG RMS ratio further confirmed consistently greater activation of BB across all joint angles. Post-hoc analyses revealed that BB activation was significantly greater at 70° compared with 90° and 110°, while TB activation was higher at 70° compared with 90° and 110°, and also higher at 90° compared with 110°.
Conclusion: The findings demonstrated that joint angle influences EMG amplitudes during MVIC for both BB and TB muscles. These findings highlight the importance of joint angle selection in exercise prescription and rehabilitation.
Keywords: Electromyography, Elbow joint, Biceps brachii, Triceps brachii, Isometric contraction.

Öz

Amaç: *Bu çalışmanın amacı, farklı dirsek açılarında biseps brachii (BB) ve triceps brachii (TB) kaslarından elde edilen maksimum istemli izometrik kasılma (MVIC) değerlerini karşılaştırmak ve bu karşılaştırmaya göre hangi açının en optimal verimliliği sağladığını belirlemektir.*
Yöntem: *Çalışmaya toplam 30 sağlıklı gönüllü katıldı. BB (dirsek fleksiyonu) ve TB (dirsek ekstansiyonu) kaslarının MVIC sırasında elektromiyografi (EMG) kök ortalama kare (RMS) genliği değerlerini ölçmek için 70°, 90° ve 110° fleksiyon açılarında EMG verileri elde edildi.*
Bulgular: *BB kasında MVIC sırasında EMG RMS genliği dirsek eklem açısına anlamlı şekilde bağlı bulunmuş olup, en yüksek aktivasyon 70°'de gözlendi. Benzer şekilde TB kasında da en yüksek aktivasyon 70°'de kaydedildi. BB/TB EMG RMS oranı, tüm açılarda BB'nin daha yüksek aktivasyon gösterdiğini ortaya koydu. Post-hoc analizlerde BB aktivasyonunun 70°'de 90° ve 110°'ye kıyasla anlamlı olarak daha yüksek olduğu, TB aktivasyonunun ise 70°'de 90° ve 110°'a göre, ayrıca 90°'de 110°'a göre anlamlı şekilde yüksek olduğu bulundu.*
Sonuç: *Bulgular, eklem açısının hem BB hem de TB kasları için MVIC sırasında EMG RMS genliği değerlerini önemli ölçüde etkilediğini göstermiştir. Bu bulgular, egzersiz reçetesi ve rehabilitasyonda eklem açısının seçiminin önemini vurgulamaktadır.*
Anahtar kelimeler: *Elektromiyografi, Dirsek eklemi, Biceps brachii, Triceps brachii, İzometrik kasılma.*

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INTRODUCTION

The force output of a muscle depends on both the recruitment patterns of motor units and the biomechanical characteristics of the muscle fibres and the muscle-tendon complex. Numerous studies have shown that changes in joint angle or muscle length significantly influence the maximal force a muscle can generate.[1] Muscle fibre length and the speed at which it changes directly influence the peak force a muscle can produce, as explained by the well-known force-length and force-velocity principles. When examining isometric contractions, it is essential to account for both muscle length and joint position as key factors affecting the estimation of maximal muscle force.[2] Despite existing research, how joint position influences motoneuron excitability patterns is not yet fully understood. Consequently, the extent to which joint angle alters the relationship between surface electromyography (EMG) signals and force production remains uncertain. These aspects are particularly important when estimating muscle force from surface EMG, as accurate neuromusculoskeletal (NMS) modelling depends on understanding the interdependent effects of joint angle, EMG amplitude, and force output.[3,4]

Many NMS models presented in the literature employ EMG data to predict muscle forces or activation levels.[5] It is essential to have a comprehensive understanding of the interrelationships between EMG, force, and joint angle to accurately model the dynamic NMS. It is conceivable that the joint angle exerts an influence on muscle recruitment or velocity coding strategies, or differential recruitment between muscles, which may in turn alter the force-EMG relationship.[6] In order for the muscles to be loaded correctly during exercises, reference values of maximum voluntary isometric contraction (MVIC) percentages at certain joint angles need to be determined. According to Boettcher et al. reference values obtained from MVIC data are essential for the normalisation of EMG signals.[7]

Several researchers have documented a systematic influence of muscle length or joint angle on EMG amplitude during MVIC regarding with the quadriceps femoris muscle,[2,3] the soleus and gastrocnemius muscles,[8] the knee extensors,[9] the biceps femoris muscle[10] and the tibialis anterior muscle.[11] In contrast, a reduction in EMG data has been observed with decreasing muscle length, as reported for the gastrocnemius[12] and quadriceps.[2] Recent evidence confirms that eccentric muscle force exceeds isometric force even in the early phase of elbow flexion. Linnamo et al.[13] demonstrated that maximal eccentric force produced by the biceps brachii (BB) and brachioradialis within the first 10° of elbow movement was significantly greater than the isometric pre-activation force measured at 80° and 110° joint angles. This early-phase enhancement was also accompanied by a steeper decline in EMG amplitude with increasing joint angle in eccentric actions. Supporting these findings, Yoshida et al.[14] reported that maximal eccentric elbow flexion strength was significantly greater than isometric strength by approximately 11.7% in healthy adults. Moreover, they demonstrated that eccentric force could be reliably estimated from isometric force and muscle thickness using regression models, providing a practical alternative to direct eccentric measurement in clinical and sports settings. However, studies on the elbow joint have indicated that alterations in joint angle do not significantly influence EMG levels during MVIC. Doheny et al.[15] showed that while MVIC torque varied across eight elbow angles, EMG amplitude during maximal voluntary contractions remained statistically unchanged in BB, brachioradialis, and triceps brachii (TB). Similarly, Akima et al.[1] found no significant effect of elbow angle (60°, 90°, 120°) on EMG root mean square (RMS) during isometric extension at submaximal to maximal levels, suggesting consistent neuromuscular activation despite changes in joint position. The variability in results suggests that the link between muscle length and peak EMG amplitude is likely influenced by the anatomical or functional characteristics of the particular muscle or joint involved.

We hypothesized that both BB and TB would exhibit the highest EMG RMS amplitudes at approximately 70° of elbow flexion, corresponding to the optimal muscle length for neuromuscular activation. This study did not measure actual force or torque output but focused solely on surface EMG amplitude. The aim of the study was to compare EMG RMS amplitudes recorded from the BB and TB muscles during MVIC at different elbow angles and to determine which angle provides optimum efficiency according to this comparison.

METHODS

Participants

This study employed a cross-sectional experimental design to compare the EMG activity of BB and TB during MVIC at different elbow joint angles. The study was approved by the Health Research Ethics Committee of Ordu University (Approval No: 2022/33) and conducted in accordance with the Declaration of Helsinki. Thirty participants (15 females and 15 males; age=20.56±1.07 years, BMI=22.16±2.27 kg/m^2) volunteered (Table 1). Inclusion criteria were being between 18 and 24 years of age, having no history of joint injuries in the past six months, no contraindications for engaging in upper extremity exercise, and willingness to voluntarily participate in the study. Participants with neuromuscular disorders, orthopaedic injuries, or active skin injuries/dermatological conditions were excluded. All participants completed a health screening questionnaire and provided written informed consent prior to participation. Data collection took place during a single session in the Performance Laboratory of the Faculty of Sport Sciences at Ordu University.

Data Collection

Data were collected from the elbow joint at various joint angles to provide input parameters for a physiologically based NMS model.[16] In alignment with this model, measurements were performed at three different elbow flexion angles (70°, 90°, and 110°) to record EMG amplitudes during MVIC of BB and TB muscles. EMG signals were recorded from the BB (during elbow flexion) and TB (during elbow extension) muscles, and MVIC testing was conducted to determine muscle activation levels. Participants were seated upright on a chair with the trunk and scapula stabilized against the chair back, and the shoulder maintained in a neutral position (0-10° abduction, neutral flexion/extension). The forearm was kept in a neutral position between pronation and supination to standardize activation, while the wrist was maintained in neutral alignment (0° flexion/extension, 0° radial/ulnar deviation). Elbow joint angles of 70°, 90°, and 110° were tested in a randomized order to avoid sequence and fatigue effects, and the order of BB and TB testing was counterbalanced across participants. For BB measurements, participants performed elbow flexion by exerting MVIC against resistance applied via a belt secured to the distal forearm just proximal to the wrist joint, with the upper arm fixed to the trunk to minimize compensatory movements (Figure 1). TB activity was assessed in an overhead elbow position, where participants generated maximum voluntary isometric contraction by extending the elbow against the resistance of the belt while maintaining the arm overhead. In both tasks, no visible joint movement occurred, ensuring that only isometric contractions were measured (Figure 2).

Figure 1. Experimental setup for BB MVIC. The arrow indicates the direction of applied resistance; no joint movement occurred during MVIC.

Figure 2. Experimental setup for TB MVIC. The arrow indicates the direction of applied resistance; no joint movement occurred during MVIC.

According to the protocol described by Konrad,[17] participants were instructed to gradually increase their force, reach their maximum effort within 3-5 seconds, and maintain that effort for an additional 3 seconds. Each condition was repeated three times with 30-60 s rest between trials. Order of conditions

was randomized to reduce fatigue and sequence bias. During all MVIC trials, contractions were strictly isometric with no visible joint movement. Resistance was applied only to maintain the predetermined joint angle, while the upper arm and trunk were stabilized against the chair back. This ensured that EMG signals represented isometric activation without confounding effects of dynamic movement. All measurements were obtained from the dominant upper limb of each participant to ensure consistency in neuromuscular activation and joint function. EMG data were sampled at 1000 Hz using wireless Ag/AgCl surface electrodes connected to a Noraxon myoMUSCLE system (Noraxon, Scottsdale, AZ, USA). Electrode placement was performed in accordance with the SENIAM (Surface Electromyography for the Non-Invasive Assessment of Muscles) guidelines. To ensure standardization, all participants were instructed and monitored by the same investigator, and verbal encouragement was provided consistently. Joint angles were confirmed using an electrogoniometer (Noraxon, Scottsdale, AZ, USA).

Signal process

Raw EMG signals obtained during MVIC were processed offline to improve signal fidelity and reduce noise. Initially, a high-pass filter with a cutoff frequency of 10 Hz was applied to eliminate low-frequency movement artefacts and baseline drift, consistent with established recommendations.[17,18] A Butterworth approximation was employed to achieve a stable and phase-preserving frequency response. Subsequently, the signals were fully wave-rectified and smoothed using a moving RMS filter with a 200 ms time window, which is widely used for estimating the amplitude envelope of EMG signals in both static and dynamic tasks.[19,20] This RMS smoothing process enabled the quantification of muscle activation levels by providing reliable estimates of average and peak EMG amplitudes. The final MVIC data presented in this study (mean, peak, and minimum values) were extracted from the RMS-processed EMG signal for each muscle, ensuring that comparisons across subjects and muscles were based on standardized and physiologically meaningful metrics.

Statistical analysis

All statistical analyses were performed using SPSS version 22.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics, including mean and standard deviation (SD), were used to summarize the data. The normality of the EMG values obtained from BB and TB muscles at 70°, 90°, and 110° during MVIC was assessed using the Shapiro-Wilk test, which indicated that the data were not normally distributed. Consequently, the non-parametric Friedman test was employed to assess whether significant differences existed among the EMG values across joint angles. Post hoc pairwise comparisons were conducted using the Wilcoxon signed-rank test. To control for the Type I error associated with multiple comparisons, Bonferroni correction was applied by dividing the standard significance level ($\alpha=0.05$) by the number of comparisons ($k=3$), resulting in an adjusted threshold of $p < 0.017$ (i.e., $\alpha'=0.05/3$). Accordingly, p-values less than 0.017 were considered statistically significant in the pairwise Wilcoxon tests.

RESULTS

For BB, EMG RMS amplitude during MVIC was significantly affected by elbow joint angle ($\chi^2(2)=12.867$, $p=0.002$, $W=0.214$). Median EMG amplitude was highest at 70° (1260.5 µV [874.3-1543.5]) compared to 90° and 110°. Similarly, TB activation differed significantly across joint angles ($\chi^2(2)=15.748$, $p <0.001$, $W=0.262$), with the highest values observed at 70° (521.5 µV [338.5-646.5]) (Table 2).

In addition, the BB/TB EMG RMS ratio was approximately 2.42 at 70°, 1.62 at 90°, and 2.05 at 110°, indicating consistently greater activation of BB compared with TB across all tested joint angles.

Post-hoc pairwise comparisons indicated that BB activation was significantly greater at 70° compared to both 90° ($Z=-3.610$, $p < 0.001$, $r=0.66$) and 110° ($Z=-2.880$, $p=0.004$, $r=0.53$). No significant difference was found between 90° and 110° ($Z=-0.524$, $p=0.600$, $r=0.10$). (Table 3).

Post-hoc analyses revealed that TB activation was significantly greater at 70° compared to both 90° ($Z=-2.443$, $p=0.015$, $r=0.45$) and 110° ($Z=-3.682$, $p < 0.001$, $r=0.67$). In addition, 90° produced significantly greater activation than 110° ($Z=-3.435$, $p=0.001$, $r=0.63$). (Table 3).

DISCUSSION

The purpose of this study was to compare BB and TB EMG RMS amplitudes across different elbow joint angles. The main finding was that both muscles showed the highest activation at 70°. The findings demonstrated that joint angle significantly influences the EMG activity of both BB and TB muscles during MVIC. The results indicated that both muscles exhibited significantly higher EMG amplitudes at 70°, suggesting that this joint position elicits the greatest neuromuscular activation.

These results align with Akima et al.[1] who reported that TB activation decreases at more extended angles (120° vs. 60°/90°). Conversely, Leedham and Dowling[21] found relatively stable BB EMG amplitudes across varying angles, suggesting muscle-specific recruitment regulation. Together, this evidence underlines the significance of joint angle in modulating motor unit recruitment and neuromuscular output.

The significantly greater BB activation at 70° than at 90° or 110° clearly supports the well-established length-tension relationship. This suggests that muscle force is maximised when the muscle is at its optimal length, i.e. not overly stretched or shortened.[22] Although actual torque/force was not measured in our study, the greater EMG RMS amplitudes observed at 70° suggest enhanced neuromuscular activation at this joint position. This finding is consistent with that of Liu et al.[23] who observed stable EMG signal quality at 90°, although maximal force production was not necessarily achieved at this angle. Onishi et al.[24] stated in a study on hamstring muscles that joint angle significantly affects both EMG activity and force output. This can be extrapolated to BB function. Our findings confirm that 70° offers clear biomechanical and neuromuscular advantages for BB isometric contraction. When more recent studies are examined, the significantly greater BB activation at 70° compared to 90° or 110° aligns with contemporary findings emphasizing the importance of optimal muscle length for neuromuscular excitation. Uwamahoro et al.[25] observed peak mechanomyographic (MMG) and torque responses of BB at mid-range angles, further supporting joint positioning as a key modulator of neuromuscular output. These findings reinforce our conclusion that the 70° elbow position elicits superior neuromuscular activation for BB MVIC and should be considered in both biomechanical modeling and functional assessment. Doheny et al.[15] conducted a study involving twelve volunteers (seven female and five male) and found similar results: the highest MVIC value was achieved at 70° for both extension and flexion. This result is consistent with the MVIC RMS results obtained at 70° in our study. Maximal force output diminishes at joint angles approaching biomechanical extremes, primarily due to alterations in anatomical parameters (e.g., reduced effectiveness of muscle moment arms), intrinsic muscular properties (e.g., suboptimal overlap of actin and myosin filaments as described by the force-length relationship), and potential neural modulation (e.g., afferent feedback from joint mechanoreceptors or the musculotendinous unit).

The TB muscle demonstrated the highest EMG RMS amplitudes obtained during MVIC at 70°, with significant reductions observed at 90° and 110°. The mean differences in EMG values obtained from the TB muscle at angles of 90° and 110° were compared. The results of this comparison indicate that the mean EMG RMS amplitudes obtained during MVIC obtained at 90° were higher than the mean EMG RMS amplitudes obtained during MVIC obtained at 110°. This pattern is consistent with the findings of Akima et al.[1] who examined the three heads of the TB (medial, lateral, and long) and reported higher RMS values at 60° and 90°, with a marked decline at 120°. The results of this study highlight the mechanical disadvantage and reduced neural recruitment that occur as the elbow approaches full extension.

In the literature, there are studies in which not only MVIC RMS values but also MVIC force were assessed across joint angles. For the elbow, Miller et al.[26] reported that performance-related feedback, particularly the combination of visual and verbal cues, significantly enhanced MVIC force in the elbow flexors. This highlights the role of sensory feedback in modulating maximal neuromuscular output. At the ankle, a study

Table 1. Participant characteristics.

	Females (n=15) Mean±SD	Males (n=15) Mean±SD	Total (N=30) Mean±SD
Age (years)	20.46±1.35	20.66±0.72	20.56±1.07
Height (cm)	168.86±6.35	178.93±6.72	173.90±8.21
Weight (kg)	61.13±8.70	73.66±9.33	67.40±10.92
Body mass index (kg/m^2)	21.40±2.59	22.92±1.64	22.16±2.27

Table 2. Median [IQR] of EMG Root Mean Square (RMS) amplitudes (μV) at different angles (N=30).

		Median [IQR] (μV)	X^2	df	p/Kendall's W
Biceps brachii	70°	1260.5 [874.3 - 1543.5]			
	90°	744.0 [574.8 - 1199.3]	12.867	2	0.002/0.214
	110°	752.0 [505.3 - 1151.5]			
Triceps brachii	70°	521.5 [338.5 - 646.5]			
	90°	460.0 [274.5 - 540.8]	15.748	2	<0.001/0.262
	110°	367.5 [227.0 - 519.3]			

IQR: Interquartile Range. Kendall's W was reported as the effect size for Friedman tests.

Table 3. Pairwise Wilcoxon Signed-Rank Test results for biceps brachii and triceps brachii (Median [IQR], z, p,r) (N=30).

		Median [IQR] (μV)	z	r	p
Biceps brachii					
70° vs 90°	70°	1260.5 [874.3 - 1543.5]	-3.61	0.66	<0.001
	90°	744.0 [574.8 - 1199.3]			
70° vs 110°	70°	1260.5 [874.3 - 1543.5]	-2.88	0.53	0.004
	110°	752.0 [505.3 - 1151.5]			
90° vs 110°	90°	744.0 [574.8 - 1199.3]	-0.52	0.10	0.600
	110°	752.0 [505.3 - 1151.5]			
Triceps brachii					
70° vs 90°	70°	521.5 [338.5 - 646.5]	-2.44	0.45	0.015
	90°	460.0 [274.5 - 540.8]			
70° vs 110°	70°	521.5 [338.5 - 646.5]	-3.68	0.67	<0.001
	110°	367.5 [227.0 - 519.3]			
90° vs 110°	90°	460.0 [274.5 - 540.8]	-3.44	0.63	0.001
	110°	367.5 [227.0 - 519.3]			

Values are presented as Median [IQR]. Effect sizes for Wilcoxon signed-rank tests were reported as $r = Z/\sqrt{N}$.

found that plantarflexion MVIC torque and medial gastrocnemius EMG amplitude were highest near neutral ankle position, and decreased as the joint moved into dorsiflexion or plantarflexion extremes.[27] These findings consistently show that EMG RMS amplitudes obtained during MVIC, in terms of both electrical activation and force, tend to decrease as the muscle moves away from its optimal length, confirming the length-dependent behaviour across multiple joints. In the literature, there are studies in which not only the MVIC RMS values of the joint angle but also the MVIC force were investigated. In these studies, joint angle was found to have a significant effect on the resulting MVIC force for both flexion and extension of the elbow joint,[28,29] knee joint[30] and ankle joint.[8] EMG RMS amplitudes obtained during MVIC decreased with increasing muscle length. Linnamo et al.[13] measured maximal voluntary MVIC RMS of elbow flexion in ten healthy male volunteers during isometric and isokinetic eccentric motion at 80° and 110° and 140° elbow angle. The study reported a significant effect of joint angle on EMG RMS during maximal voluntary contractions. The results of this study are similar to our study.

Uwamahoro et al.[25] analysed the effects of elbow joint angles on the elbow flexion torque and MMG. Their results demonstrated that both MMG RMS and torque RMS values progressively increased as the joint angle shifted from 10° to 60°, followed by a decline at more extended joint positions beyond this range. It was demonstrated that increases in the elbow flexion angle in excess of 60° resulted in a downward shift in the torque RMS. The findings indicate that near the resting muscle length approximately at 60° crossbridge formation between actin and myosin filaments is optimized. The observed reductions in force at shorter muscle lengths are likely due to filament overlap interference among adjacent actin strands, whereas at longer lengths, diminished force output is attributed to excessive separation and reduced overlap between actin and myosin filaments.[31] Furthermore, given that BB inserts at the radial tuberosity, elbow flexion causes a shortening of the muscle due to changes in the muscle's moment arm geometry. These biomechanical alterations not only influence the muscle's mechanical advantage but are also associated with neural adaptations. Specifically, variations in BB length during elbow flexion have been shown to affect surface EMG amplitude, likely due to changes in motor unit recruitment thresholds, firing rates, and the synchronization of active motor units. Moreover, the modified muscle tendon dynamics at different joint angles may influence afferent feedback from muscle spindles and golgi tendon organs, further modulating the level of neural drive delivered to the muscle. These findings also support the results of our study.

The present findings provide additional evidence regarding angle-dependent neuromuscular activation of the elbow flexors and extensors. While it is physiologically established that muscles generate maximal force near their optimal length, our study contributes by characterizing EMG RMS amplitude profiles of both BB and TB across multiple joint angles within the same cohort. This dual-muscle perspective adds novel comparative information to the literature. These results also have implications for neuromuscular efficiency, a concept describing the ratio between neural activation and muscular output.[22,1] The observed angle-dependent variations in EMG activity may reflect changes in neural drive required to maintain isometric contractions at different muscle lengths. Moreover, the BB/TB EMG RMS ratio exceeded 1.0 at all joint angles, with the highest value at 70°.[2] This finding highlights the dominance of BB activation relative to TB in isometric elbow flexion, which may provide further context for understanding co-activation patterns and joint stabilization strategies. Although our data are limited to isometric conditions, the identification of joint angles eliciting greater neuromuscular activation may inform exercise prescription and rehabilitation design. However, direct extrapolation to injury prevention protocols should be made with caution, as such applications require longitudinal and dynamic assessments.

Limitations

The primary limitation of this study is the potential for electrode displacement relative to the underlying muscle due to changes in elbow positioning, which may alter the spatial relationship between the electrode and the muscle fibres, thereby affecting the fidelity of the EMG signal and the accuracy of subsequent

measurements.[32] Given the inherent limitations of surface EMG, it is not feasible to entirely control for electrode shift, making it difficult to definitively attribute observed changes in EMG amplitude to either alterations in muscle length or electrode displacement. The second limitation is that this study assessed only isometric muscle contractions; thus, the results may not generalize to dynamic movement patterns (e.g., concentric or eccentric actions). The third limitation is that the TB muscle's three heads were not evaluated individually. The fourth limitation of this study is that actual torque or force production was not directly measured; only surface EMG RMS amplitudes were analysed. Therefore, interpretations are limited to neuromuscular activation and cannot be generalized to mechanical force output. Future research should consider differential activation across the medial, lateral, and long heads.

Conclusion

In conclusion, the present study reinforces the critical influence of elbow joint angle on both muscle activation and force production during isometric contractions of the upper arm. The findings demonstrate that a joint angle of 70° optimizes EMG RMS activity recorded during MVIC for the BB and TB muscles, aligning with the established length-tension relationship and previous literature. These results underscore neuromuscular activation, as reflected by EMG RMS amplitude, is greatest when the muscle operates at an optimal length, rather than at more extended or flexed positions. Moreover, the observed stability of EMG signals around 90°, despite not coinciding with peak force output, highlights the complex interplay between neuromuscular activation and biomechanical advantage. Collectively, these insights provide valuable implications for both clinical assessment and the design of training or rehabilitation protocols, emphasizing the importance of joint angle selection to optimize neuromuscular activation and potentially enhance functional outcomes.

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ORIGINAL ARTICLE

Predictive simulations of elevating and lowering strategies in human stumble recovery

Tökezleme sonrası toparlama sürecinde uygulanan yükseltme ve alçaltma stratejilerinin öngörücü benzetimleri

Oğuz Faik SEVEN[1], Metin BICER[2,3], Mehmet Arif ADLI[1]

Abstract

Purpose: Older adults and individuals with neuromuscular impairments face a high risk of falls, which can be mitigated by identifying effective stumble recovery strategies for rehabilitation. Studying stumble recovery through empirical methods is challenging due to injury risks and constraints on natural movement, whereas predictive neuromechanical simulations offer a viable alternative. This study aimed to use a musculoskeletal model within a predictive simulation framework to analyze human stumble recovery following anteriorly directed perturbations.

Methods: Using a simplified musculoskeletal model and a reflex-based neural controller, two different scenarios for perturbations occurring in the early (20%) and late (60%) swing phases were simulated. The kinematics of the swing leg, including hip, knee, and ankle joint angles were analyzed for similarity to real human stumble recovery. Additionally, recovery strategies were identified by tracking the swing leg's toe trajectory following perturbation.

Results: Early swing perturbations elicited an elevating strategy, increasing hip and knee flexion to clear the obstacle, while late swing perturbations triggered a lowering strategy, rapidly placing the foot to restore stability. Minor deviations from experimental data were observed, particularly in ankle dorsiflexion and swing phase duration.

Conclusion: This study highlights the effectiveness of predictive neuromechanical simulations in analyzing stumble recovery. The framework successfully replicated key recovery mechanisms, demonstrating its potential for rehabilitation, assistive device design, and fall prevention strategies aimed at enhancing mobility and reducing injury risk in vulnerable populations.

Keywords: Stumbling, Simulation, Falls, Biomechanics.

Öz

Amaç: *Düşme riski, yaşlılar ve dengeyi etkileyen nöromüsküler bozuklukları olan hastalar başta olmak üzere pek çok bireyin karşı karşıya olduğu bir durumdur. Tökezleme sonrası etkili toparlama stratejilerinin rehabilitasyon programlarına dahil edilmesi ile bu risk azaltılabilir. Ancak bu stratejilerin deneysel yöntemlerle incelenmesi, yaralanma riski ve harekette ortaya çıkabilecek kısıtlılıklar nedeniyle zordur. Bu zorlukları gidermek için, bu çalışma, öngörücü nöromekanik simülasyonlar kullanarak insanların anterior yönlü pertürbasyonlar sonrası ürettiği toparlanma hareketini analiz etmeyi amaçlamaktadır.*

Yöntem: *Basitleştirilmiş bir kas-iskelet modeli ve refleks tabanlı bir sinirsel denetleyici kullanılarak, erken (%20) ve geç (%60) salınım fazlarında meydana gelen pertürbasyonlara yönelik iki ayrı senaryonun simülasyonu gerçekleştirildi. Salınım fazındaki kalça, diz ve ayak bileği bilek eklem açıları tökezleme sonrası kurtarma hareketiyle benzerlik açısından analiz edildi. Ayrıca, pertürbasyonun ardından salınım fazındaki bacağın ayak parmağının izlediği yörünge takip edilerek modelin kullandığı kurtarma stratejileri belirlendi.*

Bulgular: *Erken salınım fazında uygulanan pertürbasyon, engeli aşmak için kalça ve diz fleksiyonunda artış ile karakterize bir yükseltme stratejisi ortaya çıkarırken, geç salınım fazında uygulanan pertürbasyon, dengeyi yeniden sağlamak amacıyla salınım fazındaki ayağın hızla yere indirilmesi ile karakterize bir alçaltma stratejisini tetikledi. Özellikle ayak bileği dorsifleksiyonunda ve salınım fazı süresinde deneysel verilerden küçük sapmalar gözlendi.*

Sonuç: *Bu çalışma, öngörücü nöromekanik simülasyonların tökezleme sonrası doğal kurtarma hareketini analiz etmedeki etkinliğini vurgulamaktadır. Gerçekleştirilen simülasyonlar, tökezleme sonrası ana toparlanma mekanizmalarını başarılı bir şekilde taklit etmiştir. Öngörücü benzetimlerle elde edilen verilerin rehabilitasyon programlarının geliştirilmesinde, yardımcı cihaz tasarımlarında ve mobiliteyi artırarak yaralanma riskini azaltmayı amaçlayan düşmeyi önleyici stratejilerin geliştirilmesinde önemli bir potansiyele sahip olduğunu göstermektedir.*

Anahtar Kelimeler: *Tökezleme, Simülasyon, Düşme, Biyomekanik.*

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INTRODUCTION

Falls are a major public health concern, particularly among older adults, who experience them at a significantly higher rate due to age-related declines in physical, sensory and cognitive functions.[1] While the risk of falls is commonly associated with the elderly, an increased susceptibility to falls is observed for other vulnerable populations such as individuals with neurological disorders including Parkinson's disease and dementia,[2] as well as stroke survivors.[3] Considering number of populations associated with high risk, the consequences of falls impose a substantial burden on healthcare systems, leading to a range of injuries such as fracture,[4] traumatic brain injuries,[5] and long-term mobility impairments.[6] These injuries contribute to extended hospital stays, rehabilitation costs, and increased mortality rates.[7] A significant proportion of falls can be prevented through early identification of risk factors, balance training, and assistive interventions.[8,9] From a biomechanical perspective, falls are defined as the sudden, unintended loss of balance that results in an individual making unintended contact with the ground or a lower surface.[10] This loss of balance often arises due to an inability to adequately recover from a destabilizing perturbation, such as a stumble. A stumble is defined as a loss of balance caused by an unexpected disturbance, such as tripping over an obstacle or encountering an uneven surface. While all falls involve a failure to regain balance, not all stumbles lead to falls, as individuals can often recover stability through neuromuscular responses. Hence, understanding the biomechanics of stumbles and the neuromuscular mechanisms underlying balance recovery is therefore critical for developing effective fall prevention strategies, ultimately reducing both individual suffering and healthcare expenditures associated with fall-related injuries.[11]

Stumble recovery involves a sequence of rapid neuromechanical responses aimed at restoring gait stability following an external perturbation. In this study, we define "stumble" as a disruption in normal walking, which can occur through various mechanisms, including foot scuffing, tripping over obstacles, or slipping on low-friction surfaces. Our focus is specifically on stumble recovery following an anteriorly directed perturbation, induced by the sudden obstruction of the swing foot by an external obstacle. This type of perturbation is particularly relevant in understanding the dynamics of stumbling during everyday activities, such as walking in crowded environments or navigating uneven terrain, where the foot may unexpectedly collide with an obstacle in front of the body. Human stumble recovery strategies are highly phase-dependent, with individuals employing different responses depending on the timing of the perturbation within the swing phase of the gait cycle. Early swing phase stumbles typically activate the elevating strategy, while late-phase stumbles trigger the lowering strategy.[12,13]

Studying stumble recovery through empirical methods is challenging due to ethical concerns and the risk of injury, resulting in limited direct data collection. Computational approaches, such as predictive simulations, provide a valuable alternative by modeling biomechanical responses to balance perturbations in a controlled, risk-free environment. These simulations integrate biomechanics, motor control, and optimization algorithms to predict human movement, offering insights into joint loading, muscle coordination, and movement strategies.[14] They not only have the potential to enhance our understanding of stumble recovery but also aid in developing interventions to improve stability and prevent falls. In rehabilitation, predictive simulations help model patient-specific movement patterns, identifying dysfunctions and informing personalized treatment plans.[15] By analyzing muscle activation and joint dynamics, they guide targeted rehabilitation exercises for individuals with impaired balance and assess the potential impact of interventions like physical therapy or surgery before implementation.[16] Additionally, they assist in designing gait-support devices, such as lower limb prostheses.[17] Within this framework, predictive simulations have the potential to address the limitations associated with experimental data collection, particularly in scenarios where direct measurement is impractical or ethically constrained.

This study aims to develop a predictive simulation framework for simulating human-

like stumble recovery following an anteriorly directed perturbation caused by the swing foot colliding with a rigid obstacle. Specifically, it focuses on simulating stumbles occurring during the early and late phases of the swing cycle, at 20% and 60% of the swing phase, respectively, to capture the phase-dependent mechanisms involved in stumble recovery. Additionally, the study introduces a framework for analyzing these recovery responses, with implications for improving gait stability and informing the design of rehabilitation and assistive devices. Ultimately, this work contributes to advancing our understanding of balance recovery during walking and the prevention of fall-related injuries.

METHODS

Participants

The simulation framework for this study were built on a validated predictive model for normal human gait developed in Veerkamp et al.[18] This framework was adopted as the foundation for our study, with modifications to simulate stumbling perturbations. The details of their simulation framework pertinent to our study are as follows and for further details on the musculoskeletal model and neural controller used in this study, readers are referred to their original work.[18]

The base framework was implemented using SCONE, an open-source predictive neuromechanical simulation software.[19] SCONE specializes in modeling and analyzing human movement dynamics, employing advanced optimization algorithms to predict movements that optimize biomechanical objectives like energy efficiency and stability. It integrates seamlessly with tools like OpenSim, providing insights into muscle activations and joint mechanics.[20]

The musculoskeletal model utilized in this study was derived from OpenSim's gait2392 model, a validated computational framework for human biomechanics.[21] Originally comprising 23 degrees of freedom to represent major joints such as the hip, knee, ankle, and lumbar spine, the model was refined to enhance computational efficiency. The motion was constrained to the sagittal plane, and the trunk and pelvis were merged into a single rigid body, reducing the models degree of freedom to nine. Although it could be argued that combining the head, arms, and trunk into a single unit may overlook certain dynamic interactions, this simplification is well justified. It is established that paraspinal muscle activation has a minimal relationship with trunk kinematics during stumble recovery. Furthermore, forward deceleration of trunk flexion is predominantly managed through passive control mechanisms or the action of hip extensors.[22]

The 92 original muscle-tendon units, modeled using Hill-type dynamics, were lumped into 18 units to streamline optimization. The feet were represented with two Hunt-Crossley contact spheres per foot, with parameters estimated through tracking simulations in SCONE. These modifications preserved essential biomechanical details, enabling the model to accurately simulate muscle activations and their contributions to joint torques during locomotion.

The neural controller used in this study is a widely recognized model for replicating muscle coordination in normal gait.[23] It uses neural feedback loops and muscle activations to simulate adaptive motor responses, mirroring human motor control during dynamic activities like walking.

The physiologically-based objective functions utilized in the optimization process include cost of transport, muscle activation, head acceleration, and ground reaction force jerk. These functions correspond to walking effort, muscle fatigue, head stability, and injury risk, respectively.

To replicate the typical progression of a stumble event followed by successful recovery (Figure 1) in predictive simulations, the optimization process begins just prior to the impact and continues across successive gait cycles until the model achieves stable locomotion. Two optimization scenarios were conducted to simulate perturbations during the early and late swing phases, corresponding to 20% and 60% of the swing phase, respectively. These phases were selected based on the available experimental data in the literature,[12,13] which primarily focuses on the early and late swing phases. Although SCONE allows for the optimization of initial model states, the initial conditions were not optimized deliberately to prevent the model from pre-adapting to the impending perturbations.

Instead, the initial states, comprising positions, velocities, and muscle activations, for both scenarios were derived from the predictive simulation results for normal gait reported in Veerkamp et al.[18] Figure 2 presents the model states immediately prior to impact for these two scenarios.

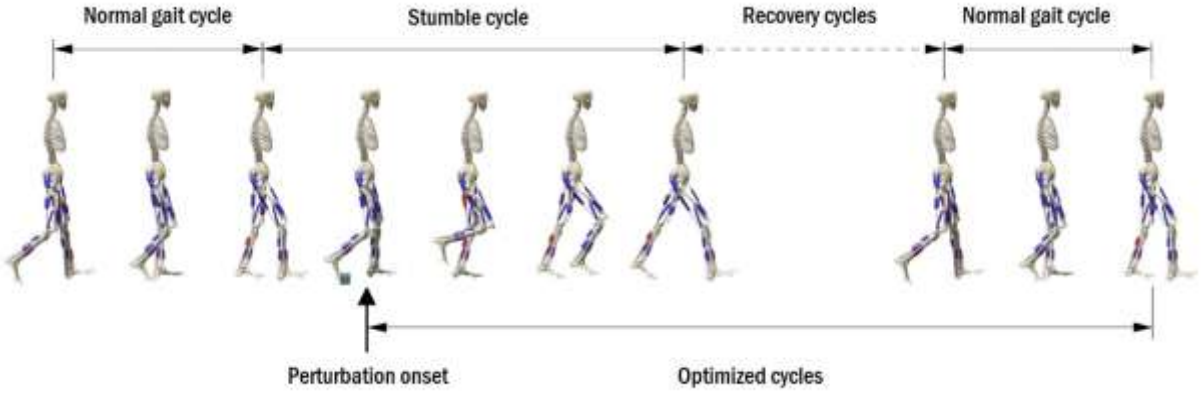

Figure 1. Typical progression of a stumble caused by obstruction of the swing foot.

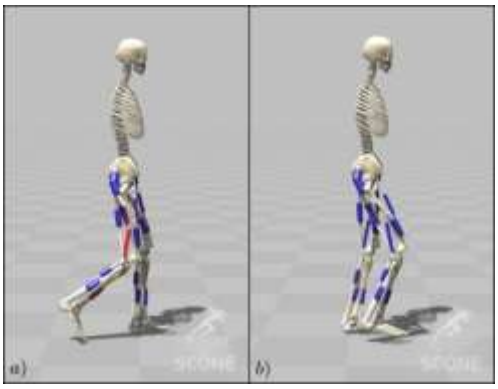

Figure 2. Initial conditions prior to stumble at a) early swing phase (20% into the swing phase) and b) late swing phase (60% into the swing phase)

To accurately replicate the perturbation caused by the obstruction of the swing foot, a constant anteriorly directed force of 100 N was applied to the tip of the model's right toe at early swing phase (20% into the swing phase) and late swing phase (60% into the swing phase) for a duration of 0.10 seconds. The magnitude and duration of the anteriorly-directed perturbation were estimated based on values reported in the literature,[24,25] where the vertical component of perturbation was found to be negligible. Therefore, we focused solely on an anterior perturbation force in our optimization.

In the optimization process, the primary objective was to minimize the cost of transport (CoT), a commonly used metric for evaluating locomotor efficiency.[18] The cost of transport quantifies the energy expenditure required for movement relative to the distance traveled and the model's mass. It was computed as:

$$CoT = \frac{1}{distance \times mass} \times \int_0^{t_{end}} \sum_{m=1}^{18} \dot{E}_m(t)\, dt$$

where $\dot{E}_m(t)$ represents the instantaneous energy consumption of the m^{th} muscle at time t, integrated over the total simulation duration t_{end}. To ensure the model has sufficient time to achieve stable locomotion, t_{end} was set to 10 seconds.

The simulation results were first evaluated based on whether the model successfully recovered from perturbation. In this context, a successful stumble recovery in the simulation

was defined based on the stability and continuity of locomotion. A fall is considered to occur if the model's center of gravity drops below a predefined threshold, at which point the simulation terminated. Recovery is considered successful only if the model achieves stable locomotion by the end of the simulation (t=10 s). Stability is quantified by assessing the similarity of consecutive gait cycles, with recovery deemed successful if the kinematics of successive cycles exhibit an R^2 value above 0.950.

For simulations that achieve successful stumble recovery, further analysis was conducted to examine the strategy selection of the model. This was done by tracking the trajectory of the swing leg's toe throughout the perturbed gait cycle. We also quantified step length and step duration during the stumble cycle. Once distinct recovery strategies were identified, the kinematics of the swing leg were compared with normative gait data derived from predictive simulations of healthy gait in Veerkamp et al.[18] which also served as the initial conditions for this study. Additionally, the recovery strategies selected by the model were qualitatively compared with experimental findings from the literature to assess their biomechanical plausibility.

RESULTS

The optimization of both early and late swing phase stumbles was successful, with each scenario achieving a stable gait cycle by the end of the simulation. The simulation framework effectively generated human-like stumble recovery motions (Figure 3-5). In the early swing phase, the swing foot followed the elevating strategy by lifting the swing leg directly over the obstacle without additional steps after impact. In the late swing phase, recovery motion mirrored the human-like lowering strategy. Unlike the early swing phase, the swing foot was placed in front of the obstacle shortly after the impact, while obstacle clearance was initiated by the contralateral (support) leg.

The elevating strategy resulted in a step length of 0.75 m and a step duration of 0.70 s during the stumble cycle. Compared to the normative values of 0.65 m and 0.56 s, respectively, this indicates an increase in both step length and duration. In contrast, the lowering strategy led to a step length of 0.21 m and a step duration of 0.44 s, showing a substantial reduction relative to normative gait. In the elevating strategy, the maximum hip flexion angle reached 47°, compared to the normative value of 33°, while the maximum knee flexion angle was 100°, exceeding the normative value of 59° (Figure 4). Conversely, in the lowering strategy, knee flexion at heel strike was 41°, higher than the normative value of 4°, while ankle dorsiflexion at heel strike was 5°, lower than the normative value of 14° (Figure 5).

DISCUSSION

In this study, we aimed to develop a framework for predictive simulations of human gait stumble recovery to overcome the limitations of empirical data collection. We achieved this by modifying an existing predictive simulation framework for healthy gait to account for perturbations caused by foot-obstacle contact. Specifically, we introduced a perturbation force at the moment of impact to simulate the destabilizing effect of stumbling. Additionally, unlike the original framework, we did not optimize the initial states of the simulation. Instead, we used pre-existing predictive simulation data of healthy gait to set the initial conditions at 20% and 60% of the swing phase, corresponding to early and late stumble events, respectively. The simulation results for both the early and late swing phases effectively captured the phase-dependent nature of the recovery motion. Previous studies indicated transition from the elevating strategy to the lowering strategy happened at an average of 44% into the swing phase.[13] In our simulations, the framework generated an elevating strategy for stumbles occurring in the early swing phase (at 20% into the swing phase) and a lowering strategy for those occurring in the late swing phase (at 60% into the swing phase). This demonstrates that the simulation framework successfully replicates the overall characteristics of the recovery response in both phases of the gait.

The main characteristics of elevating strategy involves over flexion of hip and knee

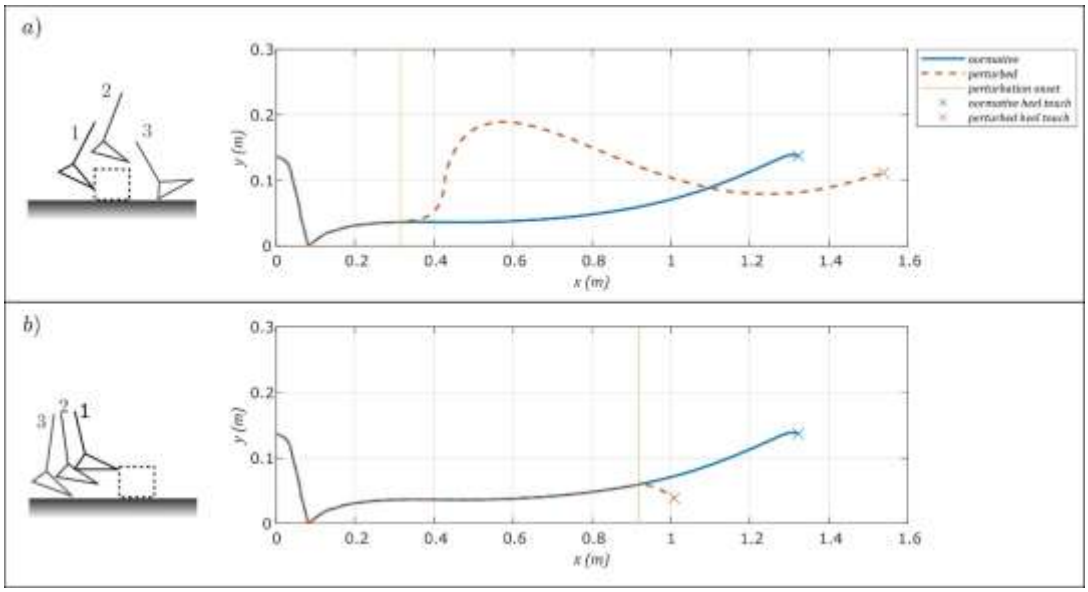

Figure 3. Schematic illustration (adapted from Shirota et al.[27]) and toe trajectory, shown in orange, of the swing leg for perturbations applied in the early swing phase (a) and late swing phase (b). The normative toe trajectory without any stumble is shown in blue for both perturbations.

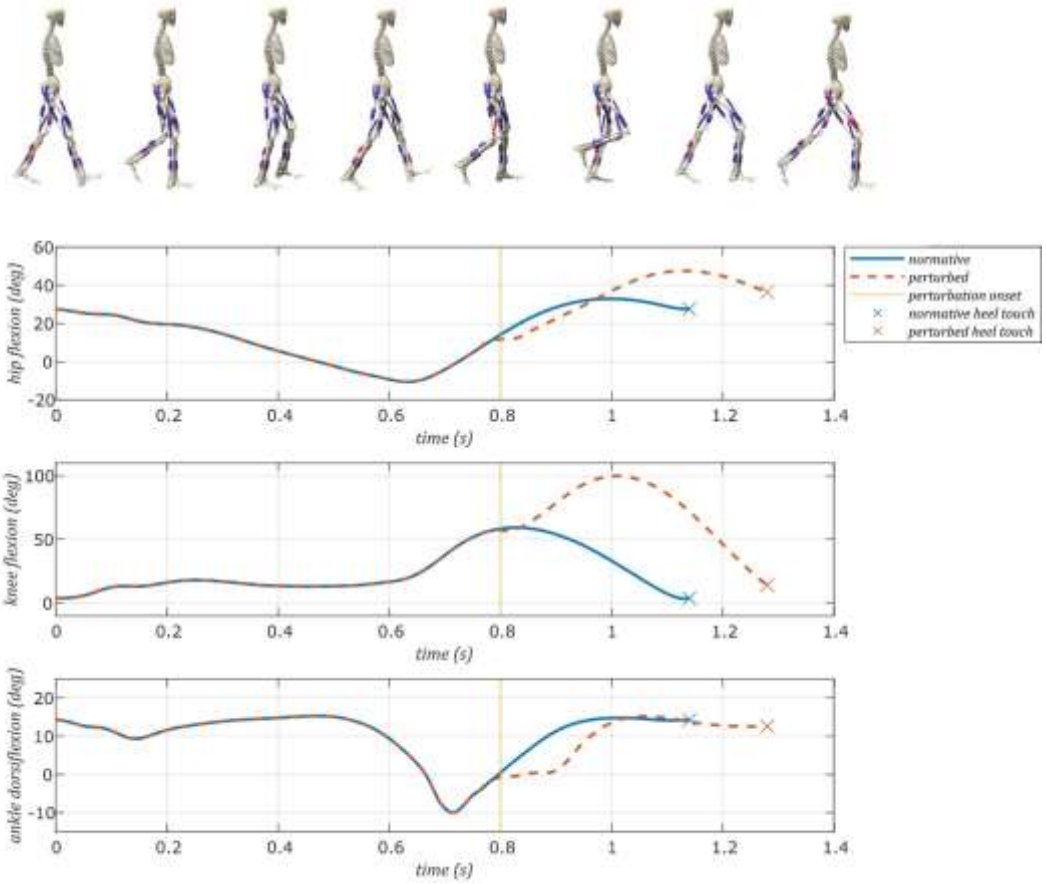

Figure 4. Sagittal plane kinematics for normative (blue) and perturbed (orange) gait. The perturbation is applied in the early swing phase (20% of the gait cycle).

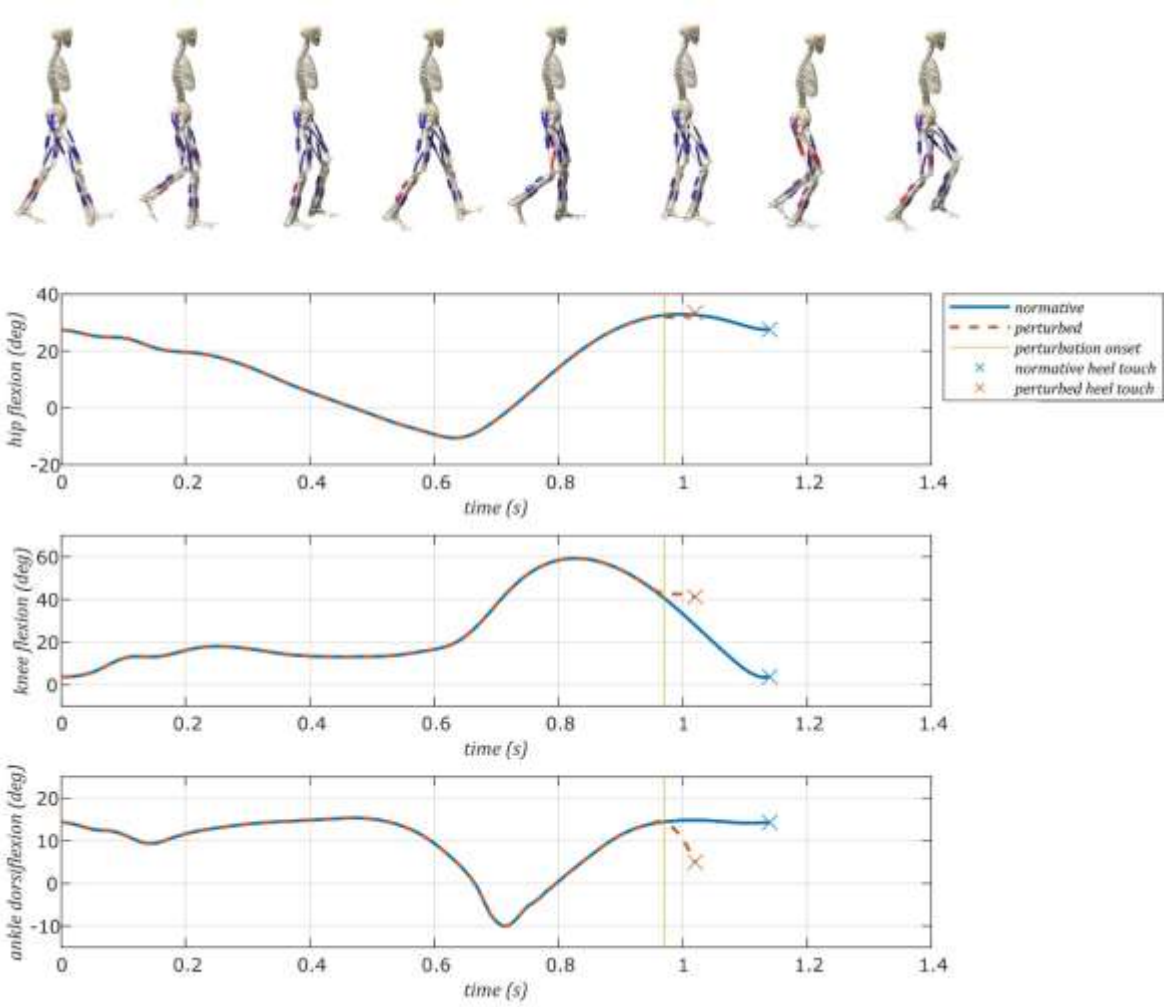

Figure 5. Sagittal plane kinematics for normative (blue) and perturbed (orange) gait. The perturbation is applied in the late swing phase (60% of the gait cycle).

joints in an attempt to lift the swing limb over the obstacle after the stumble. In the early swing phase simulation, a similar pattern is captured in these joints. As a result, over flexion of hip and knee joints enabled the model to perform the elevating strategy. However, it was observed that the ankle joint could partially capture the human like motion. Similar to the experimental data reported in Schillings et al.[13] right after the stumble the ankle is plantar flexed due to the perturbation force. After the foot is cleared from the obstacle, compared to the normative data, ankle joint is over dorsiflexed to prepare for the heel strike. In simulation, we can see that right after the perturbation force is applied the ankle joint is plantar flexed however, in subsequent section the ankle dorsiflexion remained level with the normative data.

In the lowering strategy, human movement patterns differ markedly from those observed in the elevating strategy. Following perturbation, the subsequent knee extension and ankle dorsiflexion responses are inhibited, leading to either a flattened heel contact or a forefoot landing, accompanied by increased knee flexion at the moment of landing. The movement outcomes of the lowering strategy in the late swing simulation indicate that the model exhibits forefoot landing, consistent with experimental data reported in Eng et al.[12] Furthermore, the model demonstrates minimal variation in hip flexion. Similar to the experimental findings, the knee extension and dorsiflexion responses following impact are inhibited, and foot lowering is primarily achieved through ankle plantarflexion. The perturbation at this phase prompts the model to

react more rapidly than anticipated. Experimental data suggest that the lowering strategy results in a shorter swing phase compared to the elevating strategy, although it remains longer than that observed in normative data. However, in the simulation, the model produces a significantly shorter swing phase, failing to exhibit the increased knee near heel strike.

The interaction between the swing foot and the obstacle can be characterized as an impact event, which occurs over a relatively short duration and generates substantial reaction forces.[26] Due to the impulsive nature of such events, the position variables remain continuous, while the velocities experience an instantaneous discontinuity. Consequently, a temporal delay is required for the velocity change to manifest in the positional variables: hip flexion, knee flexion, and ankle dorsiflexion. This phenomenon is also evident in the experimental data reported in.[12,13] However, in both strategies resulting from predictive simulation, joint angle variations commence immediately following the perturbation onset. This discrepancy represents a notable deviation between the simulation results and the experimental observations.

These findings are not only theoretically consistent with experimental studies but also hold strong clinical implications. The ability to simulate stumble recovery strategies with predictive accuracy supports the development of rehabilitation protocols tailored to specific phases of gait. For instance, training programs could be designed to strengthen hip and knee flexion for early-swing recovery (elevating strategy), or improve rapid foot placement and load acceptance in late swing (lowering strategy). Furthermore, the insights into altered ankle and knee mechanics during perturbation can inform the design of phase-sensitive wearable assistive devices such as smart prostheses, which must respond quickly and differently based on the gait phase to prevent a fall. By identifying neuromechanical deficiencies, such as limited ankle dorsiflexion or insufficient swing leg clearance, clinicians can target specific impairments that compromise balance recovery.

Limitations

The presented approach has some limitations. First, we assumed a constant impact force throughout the swing phase, disregarding its variation depending on the velocity of the swing foot at perturbation onset. Phase-dependent formulation of the impact force should be implemented in future works. Additionally, our analysis primarily focused on the kinematics of the swing leg, as it plays a central role in strategy selection. However, the stance leg also contributes significantly to recovery dynamics, particularly in redistributing body weight and stabilizing postural control. Future studies should incorporate a more comprehensive evaluation of stance leg mechanics to fully capture the interplay between both limbs during stumble recovery. Furthermore, the current model excluded upper limb dynamics by modelling the upper body as a single rigid body. Although this enhances the computational efficiency, the exclusion of upper limb dynamics may limit the accuracy of the simulated recovery strategies, particularly in capturing whole-body coordination. Future simulations would benefit from explicitly modeling the arms to better reflect their stabilizing role during balance recovery. Lastly, the scope of this study is limited to immediate neuromechanical responses to assess the ability of our framework to generate stumble recovery motion. However, the full stabilization process includes not only the initial corrective movement, but also subsequent adaptations in limb coordination, posture, and center of mass control. Future studies could expand the current framework to capture this extended recovery sequence. Modeling and analyzing the evolution of gait stability across multiple steps would offer a more comprehensive understanding of stumble recovery strategies and help identify subtle impairments in individuals at risk of falling.

Conclusion

This study successfully employed predictive neuromechanical simulations to model human stumble recovery strategies in response to anteriorly directed perturbations, providing valuable insights into the phase-dependent nature of these strategies. The simulation replicated key biomechanical features, demonstrating that perturbations occurring during the early swing phase predominantly trigger an elevating strategy, while those during the late swing phase elicit a lowering strategy.[12] The elevating strategy, characteristic of the early swing phase, involves lifting the perturbed limb to clear the obstacle, facilitated by increased hip flexion and knee extension, with the contralateral leg offering support.[13] In contrast, the lowering strategy, typical of the late swing phase, involves a rapid downward

movement of the perturbed limb to make immediate ground contact, stabilizing gait through increased knee flexion and rapid foot placement.[13] While the model accurately captured these kinematic characteristics, certain discrepancies, such as deviations in ankle dorsiflexion and swing phase duration, suggest areas for refinement.

These findings underscore the potential of predictive simulations for studying fall prevention and rehabilitation, particularly for populations at heightened risk of falls. By highlighting the adaptability of human gait through phase-dependent recovery strategies, this research emphasizes the critical role of neuromechanical control in maintaining stability during perturbations. Future improvements, such as enhanced impact modeling and a more thorough evaluation of stance leg contributions, will further increase the accuracy and applicability of these simulations. Ultimately, by bridging the gap between computational modeling and real-world biomechanics, this study lays the foundation for developing targeted interventions to improve stability and reduce fall-related injuries. In clinical contexts, such simulations can guide the personalization of fall-prevention interventions, particularly for older adults and individuals with compromised neuromuscular function. The phase-dependent strategies identified here can serve as benchmarks for assessing patient recovery potential and for training compensatory behaviors. Additionally, rehabilitation robotics and prosthetic control systems can be better informed by these neuromechanical patterns, enabling more adaptive and responsive support during gait perturbations.

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Conflicts of Interest: *None*

Ethical Approval: The authors declare that this study does not require Ethical Committee Approval.

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ORIGINAL ARTICLE

Cerebral palsy and nutrition: effects of gross motor function on eating behaviour

Serebral palsi ve beslenme: kaba motor fonksiyonun yeme davranışına etkileri

Hakan TOĞUÇ[1], Osman SÖYLER[2], Hakan AYDIN[3], Zehra FİDAN[4]

Abstract

Purpose: Cerebral palsy (CP) is a movement disorder that develops due to brain damage and is usually seen in childhood. Common feeding problems in individuals with CP can negatively affect health and quality of life. This study aims to investigate the effects of gross motor function on eating behaviour and nutritional status in children with CP.

Methods: This study is a cross-sectional study conducted with 50 children diagnosed with CP at a rehabilitation centre. Participants were administered socio-demographic information, The Children's Eating Behavior Inventory (CEBI), the Gross Motor Function Classification System (GMFCS), and the Paediatric Functional Independence Measure (WeeFIM); their nutritional status was measured using 24-hour food consumption records, and anthropometric measurements and muscle strength were assessed. Independent t-test, Mann-Whitney-U test, Pearson and Spearman correlations, and multiple regression analyses were used in the analysis of the data.

Results: The average age of the participants was 8.32±3.60 years, 52% were male and 48% were female. It was found that children with CP met 70.61% of their energy requirements and 53.17% of their fibre requirements. As the GMFCS level increased, WeeFIM ($p<0.001$) and CEBI-skill ($p<0.001$) decreased and underweight increased ($p=0.015$). In addition, a significant positive correlation was found between right and left quadriceps, right and left biceps, and right and left triceps muscle strength and CEBI-skill ($p<0.05$).

Conclusion: These findings demonstrate an increase in GMFCS and malnutrition in children with CP. A proper feeding strategy can positively influence motor function and general health.

Keywords: Cerebral palsy, Nutritional status, Functional status, Eating.

Öz

Amaç: *Serebral palsi (SP), beyin hasarı nedeniyle gelişen ve genellikle çocukluk çağında görülen bir hareket bozukluğudur. SP'li bireylerde sık görülen beslenme sorunları, sağlık ve yaşam kalitesini olumsuz etkileyemektedir. Bu çalışmanın amacı serebral palsili çocuklarda kaba motor fonksiyonların yeme davranışı ve beslenme durumu üzerindeki etkilerini araştırmayı amaçlamaktı.*

Yöntem: *Bu çalışma, bir rehabilitasyon merkezinde SP tanısı konmuş 50 çocukla yapılan kesitsel bir çalışmadır. Katılımcılara sosyo-demografik bilgiler, Çocukların Yeme Davranışı Envanteri (CEBI), Kaba Motor Fonksiyon Sınıflandırma Sistemi (GMFCS) ve Pediatrik Fonksiyonel Bağımsızlık Ölçeği (WeeFIM) uygulandı. Beslenme durumları 24 saatlik gıda tüketim kayıtları kullanılarak ölçüldü ve antropometrik ölçümler ile kas gücü değerlendirildi. Verilerin analizinde bağımsız t-testi, Mann-Whitney-U testi, Pearson ve Spearman korelasyonları ve çoklu regresyon analizleri kullanıldı.*

Bulgular: *Katılımcıların yaş ortalaması 8,32±3,60 yıl, %52'si erkek ve %48'i kadındır. SP'li çocukların enerji ihtiyaçlarının %70,61'ini ve lif ihtiyaçlarının %53,17'sini karşıladıkları tespit edildi. GMFCS seviyesi arttıkça, WeeFIM ($p<0,001$) ve CEBI-beceri ($p<0,001$) azaldığı ve yetersiz beslenmenin arttığı ($p=0,015$) tespit edildi. Ayrıca, sağ ve sol kuadriseps, sağ ve sol biseps ve sağ ve sol triseps kas gücü ile CEBI-beceri arasında anlamlı pozitif korelasyon bulundu ($p<0,05$).*

Sonuç: *Bu sonuçlar, SP'li çocuklarda yetersiz ve dengesiz beslenmenin yaygın olduğunu göstermektedir. SP'li çocuklarda uygun bir beslenme stratejisi, motor fonksiyonları ve genel sağlığı olumlu yönde etkileyebilir.*

Anahtar Kelimeler: *Serebral palsi, Beslenme durumu, Fonksiyonel durum, Yeme.*

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INTRODUCTION

Cerebral Palsy (CP) is a movement disorder caused by prenatal, intrapartum or postnatal brain damage and represents the most common childhood disability globally, affecting 2-3 per 1000 births.[1] While the exact origins of CP remain unclear, factors such as prenatal and intrapartum oxygen deficiency, infections and cerebral haemorrhage are known risks.[2] CP impairs muscle coordination and body movements, typically manifested by impaired motor functions, spasticity, involuntary movements and imbalance, making feeding and eating behaviours difficult.[3] Nutritional problems, inadequate food intake, swallowing difficulties (dysphagia) and gastrointestinal complications are frequently observed in individuals with CP. These problems may lead to serious consequences including growth retardation, malnutrition and decreased quality of life.[4]

Nutrition includes the intake, digestion, absorption and metabolism of nutrients necessary for growth, development and maintenance of body health. Assessment of nutritional status is critical for improving overall health and quality of life in individuals with CP. Feeding difficulties in these individuals may result from dysphagia, anorexia, inadequate chewing and gastrointestinal problems.[5] Oral-motor dysfunction is common in children with SP, characterised by irregularities in orofacial muscle tone and coordination due to central motor control impairment, impaired bolus formation/transfer, and reduced safety–efficiency of swallowing.[6] These pathomechanisms can exacerbate feeding difficulties through prolonged meal duration, inadequate intake, choking/coughing, and aspiration risk, and the severity of oral phase disorders tends to increase as the Gross Motor Function Classification System (GMFCS) level worsens.[7] As a result of this situation, nutritional problems can be observed in a significant proportion of children with CP and thus growth and development are negatively affected.[8] In a study by Donkor et al.[9] malnutrition was found in 90% of children with CP. Similarly, in a study conducted by Sullivan et al.[8] growth retardation and malnutrition were found in a significant proportion of children with CP. This shows that these individuals cannot meet their daily calorie, protein and other nutritional needs.

As the gross motor function level worsens in children with CP, postural control and selective motor control limitations increase; this negatively affects oral phase skills (chewing, bolus control) and the safety/efficiency of swallowing, leading to more frequent and severe feeding-swallowing difficulties. This relationship is supported by clinical assessment-based findings showing that oropharyngeal dysphagia increases in a graded manner with GMFCS in preschool children with CP.[7] Similarly, parent-reported studies have indicated that as gross motor function deteriorates, children's ability to consume/eat different food textures decreases; consequently, inadequate intake, prolonged meal times, and increased feeding risks are reported.[10] In this context, it is important to assess anthropometric measurements and muscle strength in the study to reveal not only the eating-swallowing function but also the physical outcome of this functional loss; as feeding difficulties can have measurable effects on dietary intake and growth, and deterioration in growth/nutrition status can further compromise functional capacity.[6] Therefore, studies addressing gross motor function level, nutritional-anthropometric measurements and nutritional status within the same framework are required for the early diagnosis of high-risk subgroups and the targeting of rehabilitation-dietetics-nutrition management according to motor severity. This study aims to examine the effects of gross motor function on eating behaviours and nutritional status in children with CP.

METHODS

This cross-sectional study was conducted at a rehabilitation centre in eastern Turkey. The study was conducted between July 2024 and December 2024. The study was approved by the İnönü University Health Sciences Non-Interventional Clinical Research Ethics Committee on 16 April 2024 in accordance with the Helsinki Declaration (Ref. No: 2024/5871). The parents responsible for the care of the

participants were informed about the study and written informed consent was obtained.

The inclusion criteria for the study were: having a diagnosis of CP, being between 3 and 18 years of age, and voluntary participation in the study as confirmed by the primary caregiver. At the start of the study, 58 participants were reached, but 5 of them were excluded from the study because they were over 18 years of age, and 3 withdrew from the study, so the study was completed with 50 participants. The data collected included socio-demographic information, The Children's Eating Behavior Inventory (CEBI), GMFCS, Paediatric Functional Independence Measurement (WeeFIM), 24-hour food records, anthropometric and muscle strength measurements.

The Children's Eating Behavior Inventory (CEBI)

This scale was developed to determine the eating behaviours of children with disabilities who require medical treatment by Archer, Rosenbaum and Streiner[11] and adapted into Turkish by Kürtüncü and Arslan.[12] It consists of 19 items on a five-point Likert scale. The scale consists of five subscales: family, skills, negativity, emotions, and permission.

The Gross Motor Function Classification System (GMFCS)

GMFCS is a standardised tool developed by Palisano et al.[13] to classify gross motor function in children with CP based on their ability to move independently, with a particular focus on sitting, transfer and mobility skills. The system consists of five levels (I–V) that reflect differences in functional limitations and the need for assistive devices. GMFCS ensures consistent and reliable classification of motor function in clinical and research settings. The Turkish adaptation and validity of GMFCS were conducted by El et al.[14] Because the distribution of GMFCS levels was markedly imbalanced in our sample, GMFCS was collapsed into two clinically meaningful categories to improve the stability of statistical comparisons: levels I–III (ambulatory/more mobile) and levels IV–V (limited mobility/non-ambulatory).

The Paediatric Functional Independence Measure (WeeFIM)

The scale is a standardised assessment tool developed to evaluate functional abilities and functional independence in children. Adapted from the Functional Independence Measure (FIM) for adults, the WeeFIM assesses 18 items across three domains: self-care, mobility, and cognition. Each item is scored on a 7-point scale indicating the level of assistance required to perform the task. This scale provides a comprehensive understanding of a child's functional abilities in daily life and is widely used in clinical and research settings related to paediatric rehabilitation. WeeFIM was developed by Kim et al.[15] and its Turkish adaptation and validity were conducted by Tur et al.[16]

Food Consumption Record

Information on children's food consumption over the past 24 hours was collected through questions asked to mothers; the amounts of food consumed were recorded in a way that mothers could express more accurately, with examples of measurement units provided.[17]

Anthropometric Measurements

Height was calculated as estimated height using validated equations appropriate for age and gender, based on stature measured with a stadiometer in children who could stand safely for measurement, or based on tibia length measured in a sitting/supine position when standing measurement was not possible. Height (cm) = 32.3 + 3.14 × Tibia length (cm) has been calculated.[18] Knee lengths and upper mid-arm circumferences (MUAC) were taken using an inflexible tape measure. Body weights were obtained with a weighing scale.[17] MUAC z-score, body mass index (BMI) z-score and height-for-age (HFA) z-score were calculated according to World Health Organisation standards.[19]

Handgrip And Muscle Strength Assessment

Handgrip strength was assessed bilaterally using a hand dynamometer (Lafayette Manual Muscle Tester, Model 01163, USA) in a standardized seated position (shoulder adducted and neutrally rotated, elbow at 90° flexion, forearm neutral, wrist in 0–30° extension and 0–15° ulnar deviation). After a standardized instruction, three trials were performed for each hand with ≥30 s rest intervals, and the mean of the three trials was used for analyses. Quadriceps, biceps, and triceps strength were evaluated bilaterally by an experienced physiotherapist using manual muscle testing (MMT; 0–5 scale). Quadriceps was tested in sitting with hip and knee at 90° flexion against resisted knee extension (resistance applied to

the distal tibia), whereas biceps and triceps were tested in sitting against resisted elbow flexion (forearm supinated) and elbow extension, respectively (resistance applied to the distal forearm).[20] All MMT procedures were performed with standardized verbal cues and stabilization to minimize compensations.

Statistical analysis

The sample size was calculated using G*Power under the assumption of an independent samples t-test to test the difference in eating behaviour scale scores according to GMFCS level (I–III vs IV–V). Based on Toğuç et al.'s[21] report of significant differences in clinical outcomes according to GMFCS levels in children with CP and the large effect size (Cohen's d≈0.80) derived from the reported group mean±SD values, a minimum total sample size of N=42 was found for α=0.05 and power=0.80. At the end of the study, data was collected from 50 participants and the study was completed accordingly.

Data analysis was performed using the IBM SPSS 22.0 software package, and food consumption records were analysed using the BeBIS 8.2 software package. To increase the stability and interpretability of comparisons between groups within the GMFCS and to reduce the risk of unreliable estimates arising from sparse groups, the GMFCS was clinically divided into two meaningful categories: Grades I-III (able to walk or more mobile) and Grades IV-V (limited mobility/unable to walk). Descriptive statistics include means, standard deviations, and percentages. Normality was assessed using histograms, the Shapiro-Wilk Test, Q-Q plots, and skewness and kurtosis within ±1.00. Intergroup comparisons were performed using the independent samples t-test for variables showing a normal distribution and the Mann-Whitney U test for variables showing a non-normal distribution. For relationship analyses, Pearson correlation was used for continuous variables showing a normal distribution, and Spearman rank correlation was used for non-normal and/or ordinal variables. The effect of demographic information and GMFCS level on eating behaviour was analysed using multiple regression analyses. Statistical significance was set at $p<0.05$.

RESULTS

The general information of the participants is shown in Table 1. The average age of the participants was 8.32±3.60 years, 52% were male and 48% were female. The father's education level of 40% and the mother's education level of 52% of the participants was primary school or below. Family income of 48% of children with CP was less than their expenses. Children's energy intake was 1237.26±391.56 kcal, carbohydrate intake 132.26±58.91 g, protein intake 47.04±16.27 g, fat intake 55.97±17.56 g, saturated fat intake 22.56±7.16 g and fibre intake 13.44±7.91 g.

Table 2 summarises the comparative analyses of WeeFIM, CEBI, anthropometric indices, and muscle strength according to participants' GMFCS levels. For analytical purposes, participants were grouped as GMFCS I–III versus GMFCS IV–V. With respect to functional independence, the GMFCS IV–V group exhibited significantly lower performance than the GMFCS I–III group across multiple WeeFIM domains. Specifically, scores were reduced for self-care ($p<0.001$), sphincter control ($p=0.009$), transfers ($p=0.004$), locomotion ($p<0.001$), communication ($p=0.003$), and social cognition ($p<0.001$). Consistent with these domain-level findings, the WeeFIM total score was also significantly lower in participants classified as GMFCS IV–V ($p<0.001$). Collectively, these results indicate that greater motor impairment is associated with broader limitations in activities of daily living, mobility, and communication-related functioning. Turning to eating behaviour outcomes, participants in the GMFCS IV–V group demonstrated significantly lower scores on the Skill subscale ($p<0.001$) and on the CEBI total score ($p=0.012$) compared with those in the GMFCS I–III group. This pattern suggests that increasing severity of motor limitation may be accompanied by less favourable eating behaviour profiles, particularly with respect to eating-related skills. In parallel, group comparisons of anthropometric measures revealed significant differences in indicators related to nutritional status. The GMFCS IV–V group had lower BMI ($p=0.028$), MUAC ($p=0.012$), and MUAC z-score ($p=0.022$) than the GMFCS I–III group. These findings imply that

Table 1. Demographic data for participants (N=50).

	n (%)
Type of birth	
Normal	22 (44)
C-section	28 (56)
Gender	
Male	26 (52)
Female	24 (48)
Seizure presence	
Yes	15 (30)
None	35 (70)
Father's education	
Illiterate	1 (2)
Primary	19 (38)
High school	19 (38)
University	11 (22)
Mother's education	
Illiterate	4 (8)
Primary	22 (44)
High school	19 (38)
University	5 (10)
Family income status	
Income exceeds expenses	2 (4)
Income and expenditure equal	24 (48)
Income less than expenditure	24 (48)
	Mean±SD
Age (years)	8.3±3.6
Birth weight (g)	2393.4±1045.5
Food consumption	
Energy (kcal)	1237.3±391.6
Carbohydrate (g)	132.3±58.9
Protein (g)	47.0±16.3
Fat (g)	56.0±17.6
Saturated fat (g)	22.6±7.2
Fiber (g)	13.4±7.9

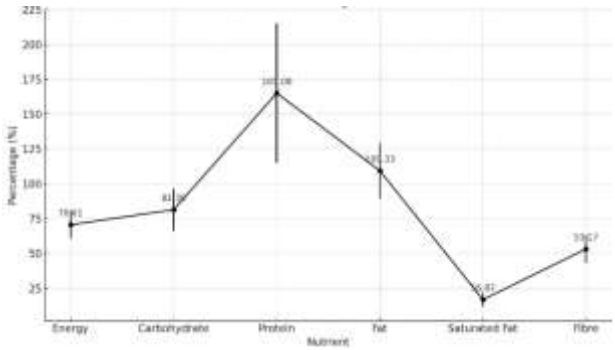

Figure 1. Comparison of participants' food consumption according to recommended daily intake.

participants with more severe functional impairment may be at greater risk of suboptimal anthropometric status. Finally, muscle strength assessments showed a consistent and marked reduction in the GMFCS IV–V group relative to the GMFCS I–III group. Strength values for the right and left quadriceps, biceps, and triceps, as well as right and left handgrip force, were all significantly lower among participants classified as GMFCS IV–V (all $p<0.001$). This uniform decrement across both upper and lower limb measures underscores the close association between higher GMFCS levels and diminished muscular strength.

The graph comparing the food consumption of the participants according to the recommended daily intake is given in Figure 1. According to the recommended daily intake, the participants met 70.61% of their energy needs, 81.39% of their carbohydrate needs, 165.08% of their protein needs, 109.33% of their fat needs and 53.17% of their fibre needs. It was also found that saturated fat intake constituted 16.82% of total energy.

Information about the relationship between participants' eating behaviour scores (CEBI) and muscle strength is given in Table 3.

Accordingly, a positive and moderately significant relationship was found between skill-related eating behaviour and right and left quadriceps, biceps and biceps ($p=0.001$; $p=0.002$; $p=0.001$; $p=0.001$; $p=0.001$; $p=0.001$; $p=0.001$; $p=0.001$; $p=0.001$; $p=0.001$; $p=0.002$, respectively). In addition, a moderately significant relationship was found between permissive eating behaviour and right triceps and between total eating behaviour scores and right biceps ($p=0.002$) and triceps and left triceps ($p=0.015$; $p=0.020$; $p=0.016$, respectively).

CEBI total score showed weak-to-moderate positive associations with muscle strength and handgrip strength (Spearman's rho=0.29–0.45, all $p<0.05$), with the strongest correlation observed for right handgrip ($p=0.45$). No significant associations were found with left quadriceps and left triceps strength ($p>0.05$). In contrast, the skill-related CEBI subscale was moderately correlated with bilateral quadriceps, biceps, triceps strength and bilateral handgrip strength ($p=0.40$-0.55, all $p\leq0.004$).

Table 2. Comparison of WeeFIM, The Children's Eating Behavior Inventory (CEBI), anthropometric measurements and muscle strength according to GMFCS levels.

	GMFCS Grade I–III (n=33) (Mean±SD)	GMFCS Grade IV–V (n=17) (Mean±SD)	p
Anthropometric measurements			
Height (cm)	121.52±22.54	112.88±16.73	0.134
Bodt weight (kg)	25.80±14.10	18.18±7.79	0.038*
Body mass index (kg/m^2)	16.31±3.75	13.87±2.94	0.028*
Mid-arm circumferences	19.09±4.31	16.47±2.92	0.015*
WeeFIM			
Self-Care	15.88±13.18	1.71±3.79	<0.001*
Sphincter control	6.79±7.23	2.35±6.52	0.009*
Transfer	9.85±10.59	3.24±10.89	0.004*
Locomotion	11.82±6.84	2.06±2.49	<0.001*
Comminication	15.97±11.20	6.24±6.08	0.003*
Social cognition	13.30±6.55	5.65±7.06	<0.001*
WeeFIM total scores	21.18±11.24	8.94±11.15	<0.001*
The Children's Eating Behavior Inventory (CEBI)			
Family	7.15±5.16	6.29±3.65	0.668
Skill	13.85±5.24	8.18±3.15	<0.001*
Negativity	6.18±3.16	5.88±3.22	0.554
Emotion	11.30±3.07	11.47±3.71	0.694
Permission	9.76±3.82	7.71±3.55	0.073
CEBI total score	48.24±12.06	39.53±9.55	0.012*
Quadriceps muscle strength			
Right	2.21±1.17	0.65±0.70	<0.001*
Left	2.15±1.09	0.59±0.71	<0.001*
Biceps muscle strength			
Right	2.18±1.16	0.35±0.70	<0.001*
Left	2.15±1.06	0.35±0.70	<0.001*
Triceps muscle strength			
Right	2.15±1.06	0.59±0.80	<0.001*
Left	2.06±1.00	0.53±0.72	<0.001*
Grip force			
Right	5.99±7.44	0.85±0.90	<0.001*
Left	5.08±4.84	0.79±0.86	<0.001*
Malnutrition scores (Z-Score)			
Body mass index (Z-Score)	2.73±1.57	2.00±1.41	0.083
Mid-arm circumferences (Z-Score)	3.48±1.30	2.59±1.23	0.022*
Height-For-Age (Z-Score)	2.36±1.27	1.65±0.86	0.054

* p<0.05. GMFCS: Gross Motor Function Classification System. WeeFIM: Paediatric Functional Independence Measurement.

Table 3. The relationship between participants' The Children's Eating Behavior Inventory (CEBI) scores and muscle strength.

		The Children's Eating Behavior Inventory (CEBI)					
		Family	Skill	Negativity	Emotion	Permission	CEBI Total
Right quadriceps	r	-0.018	0.481**	0.042	0.009	0.164	0.274
	p	0.901	0.001	0.771	0.952	0.255	0.054
Left quadriceps	r	-0.009	0.422**	0.003	-0.031	0.123	0.217
	p	0.948	0.002	0.985	0.829	0.397	0.131
Right biceps	r	-0.081	0.510**	0.028	0.200	0.264	0.343*
	p	0.574	0.001	0.848	0.164	0.064	0.015
Left biceps	r	-0.052	0.484**	-0.041	0.216	0.260	0.328*
	p	0.721	0.001	0.776	0.132	0.068	0.020
Right triceps	r	-0.020	0.459**	0.008	0.122	0.327*	0.338*
	p	0.890	0.001	0.956	0.400	0.020	0.016
Left triceps	r	-0.094	0.427**	-0.018	0.130	0.273	0.273
	p	0.514	0.002	0.903	0.367	0.056	0.055
Right grip force	rho	0.128	0.276	0.095	0.092	0.114	0.261
	p	0.375	0.052	0.511	0.524	0.429	0.067
Left grip force	rho	0.118	0.208	0.016	0.117	0.150	0.224
	p	0.414	0.147	0.913	0.417	0.298	0.118

* p<0.05. p: Pearson Correlation test. rho: Spearman Correlation test. CEBI: The Children's Eating Behavior Inventory.

Table 4. Relationship between demographic variables and the Gross Motor Function Classification System (GMFCS) group and eating behaviour (The Children's Eating Behavior Inventory, CEBI).

Predictor	B	SE	%95 CI (Lower–Upper)	p
Age	0.678	0.416	(−0.136) – (1.493)	0.103
Gender	−0.821	3.717	(−8.106) – (6.463)	0.825
Parental educational level	−3.322	2.343	(−7.914) – (1.269)	0.156
GMFCS (IV–V vs I–III)	−7.989	3.350	(−14.556) – (−1.422)	0.017

Model: F:3.61, R^2=0.243, p=0.012, multiple regression analysis model, GMFCS: Gross Motor Function Classification System, p<0.05.

The multivariate linear regression model examining the relationship between demographic variables and the GMFCS group and eating behaviour (CEBI) is presented in Table 4. In the model, when age, gender, and parental education level were controlled for, being in the GMFCS IV–V group was associated with a significant and independent decrease in the CEBI total score (B = −7.99, 95% CI: −14.56 to −1.42; p = 0.017). In contrast, age, gender, and parental education level were not found to be significant independent predictors of the CEBI total score (all p>0.05). The model showed that the variables (age, gender, parental education level, and GMFCS group) explained approximately 24.3% of the total variance in the CEBI score.

DISCUSSION

In this cross-sectional study, children with GMFCS IV–V levels demonstrated significantly lower functional independence in multiple domains and total scores of the WeeFIM compared to the GMFCS I–III group. Furthermore, as GMFCS severity increased, a more negative profile characterised by lower scores, particularly in the 'Skill' subdomain of eating behaviour and the CEBI total score, was

observed. Finally, the insufficient fulfilment of energy (70.61%) and fibre (53.17%) requirements, accompanied by lower MUAC Z-scores and marked muscle weakness in the GMFCS IV–V group, suggested that nutritional status and physical capacity may be simultaneously adversely affected in severe motor impairment.

In this study, the relationship between children's gross motor skills and feeding/eating behaviours was assessed in 50 participants diagnosed with CP. The participants' parents had a low level of education (40% of fathers and 52% of mothers had primary school education or below) and low socioeconomic status (48% of families had income below expenditure); similar findings have been reported in studies by Sel et al.[22] and Piştav Akmeşe et al.[23] These data suggest that having a child with CP may be more frequently associated with low parental educational attainment and low economic status.

As GMFCS levels increased, children's scores for self-care, transfers, communication, social cognition, and overall independence were found to decrease significantly. A study by Bakkaloğlu et al.[24] also observed similar results and found that functional independence decreased as GMFCS levels increased. Similarly, a study by Günel et al.[25] reported that WeeFIM scores decreased as the GMFCS level increased. These results demonstrated that the study findings were consistent with the literature and predicted that an increase in GMFCS scores would reduce functional independence in children.

In this study, when examining eating behaviour outcomes, participants in the GMFCS IV–V group demonstrated significantly lower scores on the skill subscale and CEBI total score compared to those in the GMFCS I–III group. This pattern suggests that increasing severity of motor impairment may be associated with less favourable eating behaviour profiles, particularly in terms of eating-related skills. One study reported that feeding difficulties and oral-motor dysfunction are highly prevalent in children with CP and that a significant proportion of clinically meaningful problems are affected.[26] Specifically, the 'motor severity–eating skill' link is reinforced by findings from a large cohort showing that the ability to eat different consistencies/textures decreases as the GMFCS level increases.[10] Furthermore, it has been demonstrated that swallowing difficulties with critical safety implications, such as oropharyngeal dysphagia, are prevalent in preschool children with CP and correlate with more severe gross motor levels; this indicates that the decline in 'eating ability' intersects not only with skill/independence but also with the dimension of safe swallowing.[7]

Methods such as age-specific MUAC z-score, BMI score, and age-specific height z-score are used to measure nutritional deficiencies in children with CP. This study found that age-specific MUAC z-scores decreased significantly as the GMFCS level increased. This indicates that the risk of malnutrition is higher in groups I-III than in groups IV-V. Similarly, another study found that the rates of thinness/underweight were very high in GMFCS V.[27] The difficulty in interpreting anthropometry in CP stems from systematic problems such as the inability to accurately measure height (contracture, spasticity, scoliosis, positioning difficulties), which leads to errors in BMI. At this point, MUAC is a practical alternative/complementary indicator as it is less dependent on height measurement. Indeed, recent evidence shows that the MUAC z-score can demonstrate good discriminatory power in screening for wasting in children with CP; although its sensitivity is limited on its own, diagnostic performance increases when combined with clinical factors.[28] Furthermore, it is emphasised that MUAC may be useful in screening the pre-school CP population; however, World Health Organisation cut-off points may need to be adapted specifically for CP.[29]

Providing adequate and balanced nutrition for children with CP is very difficult. In this study, it was found that participants met 70.61% of their energy requirements. Another study found that children with CP met 78.6% of their energy requirements.[30] Similarly, another study found that 72.4% of energy requirements were met.[31] This is thought to be due to difficulties in chewing and swallowing food and gastrointestinal complaints in children with CP. Furthermore, this study found that children's daily fibre requirements were met by 53.17%. Ecertaştan[31] found that 72.1% of children with CP consumed insufficient fibre, and Özder et al.[30] determined that children with CP met

15.8% of their daily fibre requirements. These data suggest that individuals with CP have low fibre intake, which may increase the incidence of constipation, a common complaint in CP.

A significant positive correlation was found between participants' eating skills and their right and left quadriceps, biceps, and triceps muscles. The eating behaviour and skill component (grasping the spoon/fork during eating, bringing it to the mouth, carrying it without spilling, managing the mouthful, etc.) inherently requires proximal stability of the upper extremity and distal force transmission. Biceps-triceps strength provides critical 'work capacity' for elbow flexion/extension control, smoothness of movement, and the repetitive cycle of bringing food to the mouth. Muscle rigidity and decreased muscle strength in CP can significantly affect hand/arm function and manual performance, which is reflected in bimanual/single-manual self-care tasks such as eating.[32] Weakness of the lower extremity anti-gravity muscles (including the quadriceps) may limit the 'freedom' of the upper extremity through sitting stability, pelvic control, postural adjustments, and balance strategies.[33] The moderate to high level of association between trunk control and upper extremity function reinforces this chain. In this context, quadriceps strength may be related not because it is directly the 'eating muscle' with CEBI–Skill, but because it contributes to the postural stability infrastructure that supports eating performance.[34] Along with these, Merino-Andrés et al.[35] state that strengthening these muscle groups improves motor functions and activities of daily living. In this context, skill-based eating behaviours are seen to be effective on these muscle groups, and the results of this study are consistent with the literature.

In this study, after controlling for age, gender, and parental education, the persistence of a decline in the CEBI total score at GMFCS IV–V level (B≈−7.99; p=0.017) persists, suggesting that gross motor severity is not merely a reflection of demographic/familial factors; it is a clinical predictor that can independently predict difficulties in eating behaviour/mealtime processes.[36] This interpretation is consistent with cohort findings showing that children's likelihood of acquiring the ability to eat different textures decreases as GMFCS level increases, and with studies reporting that swallowing/feeding problems (including dysphagia) are more frequent and severe at more severe gross motor levels.[10] Therefore, GMFCS IV–V should be considered a high-risk phenotype not only for mobility but also for feeding behaviour problems; systematic feeding–swallowing screening and caregiver support strategies should be incorporated into clinical follow-up for this group at an early stage.[7]

Limitations

The single-centre structure and cross-sectional design of this study limit the generalisability of the findings and complicate causal interpretations. The assessment of food intake based solely on 24-hour dietary records and entirely on parental reports, coupled with the absence of the Eating and Drinking Ability Classification System measurement, increases the risk of measurement bias.

Conclusion

This study showed that gross motor function significantly affects eating behaviours and nutritional status in children with cerebral palsy. As GMFCS levels increased, significant decreases in independence and eating skills were observed, leading to inadequate fulfilment of energy and nutritional needs. Furthermore, a positive correlation was found between eating skills and muscle strength. These findings highlight the need for well-planned nutritional strategies and programmes for children with CP that can improve motor function and overall health. Future research should aim to develop more comprehensive nutrition and health programmes to improve the quality of life of these children.

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Ethical Approval: The study was approved by the İnönü University Health Sciences Non-Interventional Clinical Research Ethics Committee on 16 April 2024 in accordance with the Helsinki Declaration (Ref. No: 2024/5871).

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ORIGINAL ARTICLE

Psychometric properties of the Turkish version of Brighton Musculoskeletal Patient-Reported Outcome Measure

Brighton Musculoskeletal Hasta Bildirimli Sonuç Ölçeği'nin Türkçe versiyonunun psikometrik özellikleri

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Abstract

Purpose: The study aimed to evaluate the reliability and validity of the Turkish cross-cultural adaptation of the Brighton Musculoskeletal Patient-Reported Outcome Measure (BmPROM).

Methods: The BmPROM was translated into Turkish (BmPROM-TR) in accordance with standardized guidelines. A total of 25 patients and 20 physiotherapists participated in the assessment of the BmPROM-TR's comprehensibility and content validity. To assess reliability, Cronbach's alpha coefficient was used for internal consistency and intraclass correlation coefficients (ICC) were used for test-retest reliability. Validity was assessed using exploratory factor analysis and correlation analysis with the subscales of the Short Form-36 Health Survey (SF-36).

Results: A total of 122 individuals with musculoskeletal problems participated in the study. Cronbach's alpha values for the functionality and well-being subscales scores were 0.721 and 0.766, respectively. The scale's functionality (ICC= 0.866) and well-being (ICC= 0.844) scores demonstrated good test-retest reliability. The Kaiser–Meyer–Olkin was 0.753 and Bartlett's sphericity test was significant (X2= 247.635, p<0.001). The BmPROM-TR was explained by bifactorial structures and 57.7% of the variation. Low to moderate positive correlations were found between the subdimensions of the SF-36 and the functionality and well-being scores (p<0.001).

Conclusion: BmPROM-TR is a reliable and valid patient reported outcome measure for assessing physical function and psychosocial factors in individuals with musculoskeletal problems.

Keywords: Patient reported outcome, Musculoskeletal diseases, Reliability.

Öz

Amaç: *Bu çalışma, Brighton Muskuloskeletal Hasta Bildirimli Sonuç Ölçeği'nin (BmHBSÖ) Türkçe kültürlerarası uyarlamasının güvenirlik ve geçerliğini değerlendirmeyi amaçlamıştır.*

Yöntem: *BmHBSÖ, standartlaştırılmış kılavuzlara uygun olarak Türkçe'ye çevrildi. BmHBSÖ'nün anlaşılabilirliği ve içerik geçerliği 25 hasta ve 20 fizyoterapist üzerinde değerlendirildi. İç tutarlılık için Cronbach alfa katsayısı, test-tekrar test güvenilirliği için ise sınıf içi korelasyon katsayıları (ICC) kullanıldı. Geçerlik, açıklayıcı faktör analizi ve Kısa Form-36 Sağlık Anketi'nin (KF-36) alt ölçekleri ile yapılan korelasyon analizi kullanılarak değerlendirildi.*

Bulgular: *Muskuloskeletal problemi olan toplam 122 kişi çalışmaya katıldı. İşlevsellik ve iyilik hali alt ölçeklerinin Cronbach alfa değerleri sırasıyla 0.721 ve 0.766 olarak bulundu. Ölçeğin işlevsellik (ICC= 0.866) ve iyilik hali (ICC= 0.844) puanları iyi düzeyde test-tekrar test güvenirliği gösterdi. Kaiser–Meyer–Olkin değeri 0,753 ve Bartlett küresellik testi anlamlı bulundu (X^2= 247,635, p<0,001). BmHBSÖ, iki faktörlü yapıyla açıklanmış olup, varyansın %57,7'sini kapsamaktadır. KF-36'nın alt boyutları ile işlevsellik ve iyilik hali puanları ile arasında pozitif düşük ile orta düzeyde anlamlı korelasyon belirlendi (p<0,001).*

Sonuç: *BmHBSÖ, muskuloskeletal problemi olan hastalarda fiziksel fonksiyon ve psikososyal faktörleri değerlendirmek için güvenilir ve geçerli bir hasta bildirimli sonuç ölçeğidir.*

Anahtar Kelimeler: *Hasta bildirimli sonuç, Kas-iskelet sistemi hastalıkları, Güvenirlik.*

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INTRODUCTION

Musculoskeletal problems (MSPs) are significant health problems with physical, economic, and psycho-social consequences. An estimated 1.7 billion people worldwide are affected by MSPs that range in severity from acute to chronic, including common disorders like osteoarthritis, osteoporosis, and low back pain.[1,2] As obesity and inactive lifestyle, which are risk factors for MSPs increase, the health cost burden of MSPs on societies is expected to increase significantly.[3]

The patient-reported outcome measures (PROMs) have been widely used to guide clinical interventions and evaluate their effectiveness.[4] These instruments are also used by clinicians and researchers to gain insight into patients' health status and to determine how effective treatments are from the patient's viewpoint.[5] Utilizing reliable and valid instruments to evaluate the efficacy of interventions is crucial. Capturing condition-specific data for multiple MSPs is challenging in routine clinical practice. Several PROMs,[6] have been widely used to assess musculoskeletal function and pain. While these instruments are valuable for assessing specific aspects of musculoskeletal health, they often focus on either functional limitations or pain intensity, with limited consideration of psychosocial factors. Given the high prevalence of MSPs, a patient-centered tool that captures both functional and psychosocial aspects is of enormous importance. This dual perspective may support clinicians in tailoring more comprehensive rehabilitation strategies. In addition, there is an increasing need in clinical practice for assessment tools that are brief, easy to administer, and capable of providing a broad perspective by evaluating both functional and psychosocial aspects. The Brighton Musculoskeletal Patient-Reported Outcome Measure (BmPROM) is a reliable and valid instrument to assess physical function and psychosocial factors in individuals with musculoskeletal problems.[7] The BmPROM has not yet been translated into another language, nor has its reliability and validity been investigated in any other language, including Turkish.

There is a lack of PROMs that can evaluate MSPs within a biopsychosocial framework without targeting a specific body part or a specific disease, and there is a need for a multidimensional scale that can be used by the Turkish-speaking population with MSPs. Therefore, the study aimed to conduct the cultural and linguistic adaptation of the BmPROM into Turkish and investigate its psychometric properties.

METHODS

This prospective methodological study was conducted in accordance with the Consensus-based Standards for the Selection of Health Measuring Instruments (COSMIN) checklist.[8] Following permission from the original scale's authors for its translation into Turkish, ethical and administrative approval was obtained from the Ethics Committee of Muğla Sıtkı Koçman University (01.07.2020) and Süleyman Demirel University Research Hospital (date 19.08.2020, document number: 30856962-044-107693), respectively.

Translation and Adaptation Process

The translation of the BmPROM into Turkish was carried out in accordance with the protocols proposed by Guillemin et al.[9] and Beaton et al.[10] Two independent clinicians (ICK and BUT) translated the BmPROM into Turkish. These two translations were evaluated by an expert committee, considering the characteristics of Turkish culture. Afterward, a common Turkish draft was created. A native English speaker (RFM) who was blind to the original document and was not a medical expert, back-translated this common draft into the original language. To ensure conceptual equivalence, the back-translation was forwarded to the scale's original author for review against the source version. Upon reviewing the back-translated version, the original developers noted that the eighth question included the phrase "depressed and broken" and requested a revision, indicating that it expressed a more severe condition than intended in the original version. Therefore, it was revised to give a "demoralized and broken down" meaning. Following comparison and approval of equivalence by the expert committee, the Turkish version of the BmPROM (BmPROM-TR) was finalized.

The comprehensibility of the BmPROM-TR was tested on 25 participants with MSPs by scoring each item with a 4-point Likert system (1=Not comprehensible, 2=A little comprehensible, 3=Quite comprehensible, 4=Completely comprehensible). The percentage of items rated as 3 or 4 points was found to be 89%, which confirms the sufficient comprehensibility of the scale.[11] To determine the content validity, 20 physiotherapists with a mean 7.7 years of professional experience (2-25 years) were interviewed. They were asked to evaluate the relevancy of each item using a 4-point Likert system (1=Not relevant, 2=Somewhat relevant, 3=Very relevant, 4=Completely relevant). The scoring indicated that the scale-level content validity index (CVI) was 0.96, indicating high content validity.[11] Overall, the high scores for comprehensibility and content validity suggest that the Turkish version is acceptable for use within the relevant patient population.

Participants

The G-Power (Mac version: 3.1.9.6) was used to calculate the sample size, and it was found that at least 97 participants would be sufficient (one-tailed dependent samples t-test, d=0.30, α level=0.05, and power level=90%). This rate was increased by 20% considering the possibility of dropping out. The study was conducted voluntarily following the Declaration of Helsinki and included patients from the Physical Therapy Department of Süleyman Demirel University who provided both verbal and written informed consent and met the inclusion criteria. Participants aged over 18 who were literate in Turkish, diagnosed with MSPs, and referred for a home exercise program were included in the study. Exclusion criteria included having any orientation, perception, or communication issues that would hinder cooperation, a history of neurological diseases, or the presence of red flag symptoms (such as fever, severe pain, sudden weight loss, etc.).

Data collection

The age (years), height (m), body weight (kg), and body mass index (BMI) (kg/m²) of the participants were recorded as physical characteristics; and sex, educational status, working status, occupation, and marital status were recorded as the sociodemographic characteristics.

After recording the diagnosis of the participants, the body regions which they had trouble in and which interfered with carrying out daily life activities (job, housework, hobbies, etc.) during the last year, as well as the body regions with trouble in the last week were evaluated by the Nordic Musculoskeletal Questionnaire (NMQ). Since our study included a wide range of musculoskeletal issues, the NMQ was used to gather information about the participants' MSPs. This scale, which was developed by Kuorinka et al.[12] and translated into Turkish by Kahraman et al.[13] includes 27 items, each rated as 'yes/no' to explore the presence of musculoskeletal symptoms at nine different parts of the body (neck, shoulder, elbow, wrist, upper body, lower body, hip, knee, and ankle).

To assess the consistency of the BmPROM-TR, participants filled out the scale twice, ten days apart. Following their diagnosis, due to the constraints of the pandemic period, the patients were referred to the home exercise program and completed the scale on the same day. In addition, they were provided with a blank version of the scale in a sealed envelope, dated 10 days later. After 10 days, the patients were contacted again by phone, and their responses were recorded. The original scale consists of eight questions and two subscales (functionality and well-being) to evaluate the individuals with MSPs in a multidimensional way including the quality of life (QoL) (Item-1), pain (Item-2), leisure or social activities (Item-3), activities of daily living (Item-4), medication use (Item-5), sleep (Item-6), anxiety (Item-7) and mood levels (Item-8). The responses to these questions are rated on an 11-point Likert scale (0-10), respectively. When rating, the scores of the 2nd, 6th, 7th, and 8th items are reversed. The scores of the 1st, 3rd, and 4th items are used to calculate the 'functionality' score, and the 2nd, 5th, 6th, 7th, and 8th items are used to calculate the 'well-being' score. Both subscale scores are rated between 0 and 10, with higher values representing a more favorable health status. The original scale demonstrated internal consistency with Cronbach's alpha values of 0.85 for functionality and 0.80 for well-being.[7] At the end of the scale, there are optional pre-treatment and post-treatment sections where individuals can list their expectations from physiotherapy treatment and physiotherapists.

These sections were not included in the analysis. It takes an average of 5 minutes to complete the scale.

The Short Form-36 Quality of Life Scale (SF-36), which was developed by Ware et al.[14] and translated into Turkish by Koçyiğit et al.[15] was used to analyze the convergent validity of the Bm-PROM-TR. The SF-36 assesses the health-related QoL of patients in eight dimensions of health under two general subheadings (physical and mental components). While the physical component consists of the general health, physical function, physical role difficulty, and body pain subscales, the mental component consists of the mental health, emotional role difficulty, energy/vitality, and social function subscales. Since the scale does not have a single scoring system, scores are calculated separately for each of the eight dimensions and range between 0 and 100. Overall health improves as the score increases.

Statistical analysis

All statistical analyses were performed using SPSS 28.0.1.1(14) MacOSx (IBM Corp., Armonk, NY). Data normality was assessed by examining skewness and kurtosis values, along with histogram plots. The descriptive quantitative data of the study were expressed as mean and standard deviation (Mean±SD), whereas qualitative data were expressed as numbers (n) and percentages (%).

The reliability of the BmPROM-TR was evaluated through test-retest reliability and internal consistency analyses. To evaluate internal consistency, Cronbach's α coefficient and item-total correlation analyses were performed. Cronbach's α was considered 'high' if >0.80, 'moderate' if between 0.60-0.79, and 'low' if <0.59. The item-total correlation for each item and the Cronbach's alpha coefficient upon deletion of each item were computed. The intraclass correlation coefficient (ICC) and a 95% confidence interval (CI) were used to analyze the scale's test-retest reliability. The reliability values of the ICC at a 95% CI were classified as follows: poor (<0.50), moderate (0.50 to 0.74), good (0.75 to 0.90), or excellent (>0.90).[16] To assess test-retest reliability, the scale was reapplied 10 days later. The floor and ceiling effects were investigated by analyzing the percentage of participants who scored highest or lowest.[17] To avoid floor and ceiling effects, the lowest and highest-scoring participants should be less than 15%.[18]

Exploratory Factor Analysis (EFA) was used to investigate the construct validity of BmPROM-TR. The varimax method was chosen for EFA. Principal component analysis was used to determine the factors of the scale. Initially, Kaiser–Meyer–Olkin (KMO) test values were calculated to check whether the data were suitable for factor analysis. The KMO values range from 0 to 1, and values >0.50 are considered suitable for factor analysis.[19,20] To determine whether the data were appropriate for factor analysis, Bartlett's Test of Sphericity was conducted[21] and a significant Bartlett Test of Sphericity indicated that the scale was suitable for factor analysis.[20] A scree plot and eigenvalues ≥1 were used to decide the number of factors.[22,23]

The convergent validity was analyzed by Spearman's correlation analysis using the scores of the BmPROM-TR and the Turkish version of SF-36 as in the original study. The correlation coefficients were interpreted as strong if r>0.60, moderate if r= 0.30-0.59, and low if r<0.29.[24] Statistical significance was set at the 95% CI and the p<0.05 level.

RESULTS

The study included 122 participants (78 women and 44 men), aged between 18–74 years (43.13±14.05). As presented in Table 1, women had higher mean age and BMI values, and a lower rate of paid employment compared to men. The educational level of the sample was low, and only 27.1% had a university degree (p>0.05). The majority of participants were married. The participants' mean scores from the functioning and well-being subscales were 5.83±2.29 and 4.82±2.36, respectively.

The most common diagnoses of the participants were cervical/lumbar disc hernia (27.05%), gonarthrosis/patellofemoral pain syndrome (13.1%), tendinitis (13.1%), and myofascial pain/fibromyalgia (9.8%). These diagnoses were related to the MSP complaints in the low back (23%), knee (18.9%), shoulder (13.9%), upper back (13.1%) neck (9.8%), and other body regions (21.3%). According to the NMQ data (Table 2), the participants have experienced MSP mostly in the lower back

Table 1. The demographic and clinical characteristics of patients (N=122).

		Mean±SD
Age (year)		43.13±14.05
Body Mass Index (kg/m²)		27.57±5.71
BmPROM-TR	Functionality	5.83±2.29
	Functionality Re-test	6.10±2.25
	Well-being	4.82±2.36
	Well-being Re-test	5.57±2.32
SF-36	Physical function	60.86±25.79
	Role function	31.35±34.40
	Role emotion	41.25±41.78
	Energy/Vitality	44.95±23.34
	Mental health	56.75±23.57
	Social function	56.04±27.56
	Bodily pain	38.75±21.21
	General health	49.67±22.13
		n (%)
Gender	Women	78 (63.9)
	Men	44 (36.1)
Educational status	Primary education	56 (45.9)
	High school	33 (27)
	Bachelor's degree	33 (27)
Working status	Not working	72 (59)
	Working	50 (41)
Occupation	Housewife/Retired	59 (48.4)
	White-collar worker	19 (15.6)
	Blue-collar worker	31 (25.4)
	Student	7 (5.7)
	Unemployment	6 (4.9)
Marital status	Married	88 (72.1)
	Single	34 (27.9)

BmPROM-TR: The Turkish version of the Brighton Musculoskeletal Patient-Reported Outcome Measure. SF-36: Short-Form36-Item Health Survey.

Table 2. Regional distribution of musculoskeletal problems according to the Nordic Musculoskeletal Questionnaire (NMQ) (N=122).

	Q1 (Yes)	Q2 (Yes)	Q3 (Yes)
	n (%)	n (%)	n (%)
Neck	78 (44)	48 (39.3)	67 (54.9)
Shoulders	76 (62.3)	39 (32)	59 (48.4)
Elbows	48 (39.3)	26 (21.3)	36 (29.5)
Wrists/hands	54 (44.3)	36 (29.5)	44 (36.1)
Upper back	79 (64.8)	43 (35.2)	60 (49.2)
Low back	85 (69.7)	55 (45.1)	76 (62.3)
Hips/tights	64 (52.5)	42 (34.4)	51 (41.8)
Knees	83 (68)	62 (50.8)	69 (56.6)
Ankles/feet	62 (50.8)	41 (33.6)	49 (40.2)
Above the waist	106 (86.9)	82 (67.2)	26 (21.3)
Below the waist	109 (89.4)	79 (64.8)	28 (23)
Axial skeleton	108 (88.5)	77 (63.1)	32 (26.2)

Q1: Have you at any time during the last 12 months had trouble (ache, pain, discomfort)? Q2: Have you at any time during the last 12 months been prevented from doing your normal work (at home or away from home) because of the trouble? Q3: Have you had trouble at any time during the last 7 days?

Table 3. Internal consistency of the BmPROM-TR's items and subscales.

	Item-total correlation (r)	Cronbach's α if item deleted	Cronbach's α
BmPROM-TR			0.739
BmPROM-TR-Functionality			
BmPROM-TR 1	0.387	0.721	
BmPROM-TR 3	0.217	0.751	0.721
BmPROM-TR 4	0.448	0.709	
BmPROM-TR-Well-being			
BmPROM-TR 2	0.326	0.731	
BmPROM-TR 5	0.513	0.696	
BmPROM-TR 6	0.573	0.681	0.766
BmPROM-TR 7	0.468	0.705	
BmPROM-TR 8	0.522	0.693	

BmPROM-TR: Turkish version of the Brighton Musculoskeletal Patient-Reported Outcome Measure.

(69.7%), knees (68%), upper back (64.8%), and shoulders (62.3%) at any time in the last 12 months. During this period, knees (50.8%), lower back (45.1%), neck (39.3%) and upper back (35.2%) were reported as the most common regions with MSP, which interfered with carrying out everyday activities. The most common body regions with trouble in the last week were the low back (62.3%), knees (56.6%), neck (54.9%), and upper back (49.2%).

Internal consistency

Internal consistency of the BmPROM-TR was evaluated using Cronbach's α coefficient and item-total correlation analyses. The overall internal consistency of the BmPROM-TR was quite reliable, with a Cronbach's alpha coefficient of 0.739. Item-total correlations varied from 0.217 to 0.573. The third question had the lowest item correlation (0.217), so the third item was deleted and the internal consistency analysis was redone. As there was no significant change in Cronbach's α value (α=0.739) as a result of the analysis, no changes were made. The pre-treatment and post-treatment sections considered optional in the BmPROM-TR were not included in the analysis.

The Cronbach's α values of the BmPROM-TR were 0.721 for the functioning subscale and 0.766 for the well-being subscale. The item-total correlations of functionality and well-being subscales are shown in Table 3.

Test-retest reliability

Test-retest reliability was assessed by re-administering the BmPROM-TR to 67 patients 10 days after the initial assessment. The ICC values of test-retest reliability for each item of the BmPROM-TR ranged from 0.646 to 0.859. For the subscales of the BmPROM-TR, a good level of test-retest reliability was found using the ICC and a 95% CI (Table 4).

Floor and ceiling effects

The lowest and highest scoring participants should be less than 15% to avoid floor and ceiling effects.[18] In the functionality score, 1 participant (0.81%) received 0 points, and 5 participants (4.09%) received 10 points. In the well-being score, 3 participants (2.46%) received 0 points, while 1 participant (0.81%) received 10 points. Therefore, no ceiling or floor effect was found in the functionality and well-being scores.

Construct validity

The KMO (0.753) and Bartlett's test of sphericity ($\chi^2 = 247.635$, $p< 0.001$) indicated the adequacy of the sample size and suitability of the data for factor analysis. Eigenvalues for two factors were found to be greater than 1. The BmPROM-TR questions' factor loadings range between 0.52 and 0.82 (Table 5).

Researches suggest that variance rates for factor analysis range between 40% and 70%.[25,26] Exploratory factor analysis showed that BmPROM-TR had two-factor structures explaining 57.7% of the total variance, which is acceptable. The first factor, which explains 36.09% of the common variation, consists of five well-being-related items (BmPROM-TR 2, 5, 6, 7, and 8). The second factor consists of three items (BmPROM-TR 1, 3, and 4) that are related to Functionality and explain 21.6% of the

common variance.

Convergent validity

Spearman's correlation analysis was conducted to evaluate the convergent validity of the BmPROM-TR with the SF-36 scores (see Table 6). The functionality score showed a low level of positive correlation with the physical and emotional role difficulty subscales of the SF-36. The well-being score showed a moderate positive correlation with all subscales of the SF-36 ($p<0.01$).

Table 4. Test–retest reliability of the BmPROM-TR items and subscales.

	ICC (%95 CI)
BmPROM-TR-Functionality	0.866 (0.782-0.918)
BmPROM-TR 1	0.646 (0.424-0.782)
BmPROM-TR 3	0.755 (0.601-0.849)
BmPROM-TR 4	0.737 (0.572-0.838)
BmPROM-TR-Well-being	0.844 (0.746-0.904)
BmPROM-TR 2	0.768 (0.623-0.857)
BmPROM-TR 5	0.859 (0.771-0.914)
BmPROM-TR 6	0.776 (0.635-0.862)
BmPROM-TR 7	0.712 (0.531-0.823)
BmPROM-TR 8	0.682 (0.483-0.805)

BmPROM-TR: Turkish version of the Brighton Musculoskeletal Patient-Reported Outcome Measure. ICC: The intraclass correlation coefficient. CI: Confidence interval.

Table 5. Factor loadings of the Turkish version of the Brighton Musculoskeletal Patient-Reported Outcome Measure (BmPROM-TR).

	Factor Loading	
	Factor 1	Factor 2
BmPROM-TR 1		0.78
BmPROM-TR 2	0.52	
BmPROM-TR 3		0.78
BmPROM-TR 4		0.80
BmPROM-TR 5	0.64	
BmPROM-TR 6	0.72	
BmPROM-TR 7	0.80	
BmPROM-TR 8	0.82	
Eigenvalues	1.732	2.888
Variance (%)	21.650	36.098
Total Variance (%)	57.748	

Table 6. Correlation analysis results of the Turkish version of the Brighton Musculoskeletal Patient-Reported Outcome Measure (BmPROM-TR) and subsections of Short Form-36 Quality of Life Scale (SF-36).

	BmPROM-TR	
	Functionality	Well-being
SF-36	r	r
General health	0.496*	0.508*
Physical function	0.559*	0.421*
Role function	0.293*	0.384*
Bodily pain	0.466*	0.520*
Mental health	0.392*	0.469*
Role emotion	0.244*	0.376*
Energy/Vitality	0.441*	0.519*
Social function	0.408*	0.501*

* $p<0.001$.

DISCUSSION

According to the study results, the BmPROM-TR is a reliable and valid outcome measure for Turkish-speaking individuals with MSPs. As no validity or reliability studies have been conducted in other languages to date, the findings were compared only to the original English version of the scale. Given the lack of studies in different languages or populations, these results provide initial evidence of the scale's reliability in a Turkish-speaking population.

Given the multifaceted nature of musculoskeletal pain, its assessment is recommended to include physiological, behavioral, neuroimaging, and patient-reported measures.[27] In this context, the use of PROMs is of great importance. While the literature includes various patient-reported outcome measures developed for specific MSPs or body regions,[28,29] there is a lack of instruments that can be used across all MSPs within a biopsychosocial framework. The BmPROM-TR is a concise and practical instrument that captures both functional and psychosocial aspects—a feature it shares with the Musculoskeletal Health Questionnaire (MSK-HQ-TR).[30] This dual perspective supports clinicians in tailoring individualized rehabilitation strategies while maintaining the

brevity necessary for clinical practice. However, a significant distinction exists in their validation samples. While the MSK-HQ-TR was validated in a sample restricted to patients with axial spondyloarthritis, the BmPROM-TR was specifically tested in a broader population of individuals with different MSPs. This difference highlights the strength of the BmPROM-TR in offering a more generalizable tool for clinical and research settings where diverse patient populations are encountered.

Cronbach's α for the functionality and well-being subscales of the BmPROM-TR was found to be 0.721 and 0.766, respectively. In the original version study, Cronbach's α for the functionality and well-being subscales was reported as 0.85 and 0.80, respectively. Cronbach's α values for the functionality and well-being subscales in this study are lower than those in the original version but are still considered acceptable according to the literature. Items may be answered differently based on participants' overall health perceptions and health literacy, which are influenced by demographic and socioeconomic factors. These factors have been shown to affect how patients complete and interpret PROMs.[31] Although the original study did not report participants' educational levels, the current study population included a relatively lower education level, which may affect health literacy and, in turn, influence how individuals interpret the functional and psychosocial constructs, potentially explaining the observed difference in internal consistency compared to the original, likely higher-literacy sample. However, as no other studies have evaluated the BmPROM-TR in different languages or populations, direct comparisons are limited, and further research is needed to confirm the consistency of these findings.

Unlike the original version study, item-total correlations were examined in this study. The lowest item-total correlation value was observed in the third question (0.217). This question encompasses activities such as dining out, sports, and social gatherings, which are highly dependent on social participation and environmental circumstances. Moreover, many participants in the study had lower educational attainment and lower socioeconomic status, factors that have been associated with reduced engagement in social and leisure activities.[32] Consequently, these demographic, socioeconomic, and cultural characteristics may have contributed to lower scores on this item, potentially explaining its lower item–total correlation. Although Cronbach's α was recalculated considering this item, it was not removed from the scale, as the resulting value remained very close to the overall internal consistency coefficient.

The test-retest method involves applying the scale to the same participants at different time points to evaluate its consistency over time.[33] To assess the test-retest reliability of the BmPROM-TR, the scale was re-administered to the patients 10 days after the initial evaluation. The literature suggests that involving 25-50% of the participants from the initial measurement is adequate for evaluating test-retest reliability.[34] Hence, test-retest reliability was evaluated using the ICC with 67 patients. The ICC values ranged from 0.646 to 0.859 for all items, indicating good reliability.[16] The ICC values for the functionality and well-being subscales of the BmPROM-TR were determined to be 0.866 and 0.844, respectively. In the original version study, the ICC value for the functionality and well-being subscales was 0.84. These results were found to be quite similar to those of the original version.

The EFA revealed that the current study exhibited a two-factor structure, consistent with the original version, comprising 'functionality' (items 1, 3, and 4) and 'well-being' (items 2, 5, 6, 7, and 8). As a result of the rotational component varimax, each item was loaded with a single factor and factor loads for all items were greater than 0.30. In the literature, factor loadings greater than 0.30 are generally considered significant.[35] Therefore, no items were removed from the Turkish version. The confirmation of the two-factor structure observed in the original version strongly supports the construct validity of the BmPROM-TR, suggesting the Turkish version maintains the intended conceptual framework across cultures. Furthermore, no other studies are available for direct comparison.

To evaluate convergent validity in this study, the correlation between the subscales of the BmPROM-TR and the total scores from the subscales of the SF-36 was analyzed. Significant moderate positive correlations were observed, particularly in the domains of General

Health, Physical Function, Pain, Energy/Vitality, and Social Function, indicating that higher functionality and well-being are associated with better physical health and reduced pain. Compared with the original study, the overall trends were similar, though correlations were generally lower for Physical Function and Social Function, possibly reflecting cultural and demographic differences between the populations. These results suggest that while the scales assess related constructs, the BmPROM-TR likely captures unique, musculoskeletal-specific aspects of a patient's condition that are not fully reflected in the SF-36. This finding is consistent with the conceptualization of the BmPROM-TR as a musculoskeletal-specific measure rather than a generic health tool. Nonetheless, further studies involving diverse populations are needed to validate the consistency and applicability of these results across different cultural contexts.

Limitations

This study has some limitations. First, there is no other cross-cultural version of the BmPROM available for comparison, which limits contextualization of our results. Second, the MSPs were not homogeneously distributed across body regions, and participants' educational levels varied. Third, the COVID-19 pandemic necessitated a single-center design, potentially limiting generalizability. Finally, confirmatory factor analysis was not performed and should be considered in future studies.

Conclusion

To the authors' knowledge, this study is the first to investigate the psychometric properties of the BmPROM in a language other than the original. The BmPROM-TR was found to be a valid and reliable scale for evaluating pain, physical function, and psycho-social factors in the multidimensional assessment of MSPs. Given its simple language, ease of completion in a short time, and straightforward scoring process, the BmPROM-TR is likely to be favored by healthcare professionals and is expected to lead to significant time and labor savings.

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