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ORIGINAL ARTICLE

Analysis of functional hop test with dual task on injured and uninjured athletes

Yaralanma geçmişi olan ve olmayan sporcularda fonksiyonel sıçrama testlerinin ikili görev ile analizi

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Abstract

Purpose: Maladaptive neuroplasticity may develop after injury. However, most of the test applications in the return to the sport process mainly focus on the motor end of the sensorimotor system. In this study, we aimed to examine the performance outputs of the functional hop tests with the dual task methodology.

Methods: Triple hop for distance (THD), crossover hop for distance (CHD) and 6-meter hop for timed (6MHT) tests were done. For the cognitive task the backward digit span test of the Wechsler intelligence scale was preferred. Nineteen athletes with a history of unilateral lower extremity injuries were assigned to the previously injured group (PIG), and 20 athletes with no previous injury were assigned to the control group (CG).

Results: There were no significant differences between the results of the cognitive task levels and Mini Mental State Examination scores of the athletes in our study (p>0.05). PIG athletes showed significantly lower jump performances compared to CG athletes; in the injured extremity side, differences were found between the groups' THD, CHD, and 6MHT values during a single task (p<0.05) and differences were also found between the THD and CHD values of the groups during the dual task (p<0.05). In the non-injured extremity side, differences were found between the THD, CHD and 6MHT values of the groups during a single task (p<0.05) and differences were also found between the groups' THD, CHD, and 6MHT values during dual task (p<0.05).

Conclusion: Results of this study indicated that some functional/cognitive deficits were still not recovered or/and differentiated neuromuscular control that may develop after injury. The dual task should be preferred during functional performance tests due to its beneficial contributions in the evaluation of athletes.

Keywords: Dual task, Functional hop tests, Sport injuries.

Öz

Amaç: *Yaralanma sonrası mal-adaptif nöro-plastisite gelişebilir. Ancak spora dönüş sürecindeki test uygulamalarının çoğu, ağırlıklı olarak duyu-motor sistemin motor ucuna odaklanır. Bu çalışmada ikili görev metodolojisi ile ölçüldüğünde fonksiyonel sıçrama testlerinin performans çıktılarının incelenmesi amaçlandı.*

Yöntem: *Üç adım sıçrama (Triple Hop Distance- THD), çapraz sıçrama (Crossover Hop Distance-CHD) ve 6-metre sıçrama (6-m Hop for Timed-6MHT) testleri yapıldı. Bilişsel görev için Wechsler zekâ ölçeğinin geriye doğru rakam aralığı testi tercih edildi. Tek taraflı alt ekstremite yaralanması öyküsü olan 19 sporcu daha önce yaralanması olan gruba (PIG) ve daha önce yaralanması olmayan 20 sporcu kontrol grubuna (CG) ayrıldı.*

Bulgular: *Çalışmamızda sporcuların bilişsel görev düzeyleri ve Mini Mental Durum değerlendirmesi puanları arasında anlamlı fark yoktu (p>0.05). PIG sporcuları, CG sporcularına kıyasla önemli ölçüde daha düşük atlama performansları gösterdi; yaralanmalı ekstremite tarafında grupların tek görev sırasındaki THD, CHD ve 6MHT değerleri arasında farklılık bulundu (p<0,05) ve ikili görev sırasında grupların THD ve CHD değerleri arasında da farklılıklar bulundu (p<0,05). Yaralanmayan ekstremite tarafında grupların tek görev sırasındaki THD, CHD ve 6MHT değerleri arasında farklılık bulundu (p<0,05) ve ikili görev esnasında grupların THD, CHD ve 6MHT değerleri arasında da farklar bulundu (p<0,05).*

Sonuç: *Bu çalışma, yaralanma sonrası bazı fonksiyonel ve/veya kognitif eksikliklerin henüz düzelmediğini ve/veya yaralanma sonrası gelişebilecek farklılaşmış nöromüsküler kontrolün olduğunu gösterdi. Sporcuların değerlendirilmesinde faydalı katkıları nedeniyle ikili görevin fonksiyonel performans testleri sırasında tercih edilmesi önerilmektedir.*

Anahtar kelimeler: *İkili Görev, Fonksiyonel sıçrama testleri, Spor yaralanmaları.*

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INTRODUCTION

Lower extremity injury rates are high during sportive activities where jumping and sudden deflected movements are high (basketball, football etc.). It has been reported that maladaptive neuroplasticity that can develop after injury.[1]

Strong evidence has been presented that the risk of subsequent injuries in different body parts is increased, especially in athletes who have undergone inadequate rehabilitation process.[2] As a possible reason for this situation, unlike the clinical environment, where the internal focus instructions are more intense, during athletic competition the stimuli from the external environment increase and/or the cognitive demand levels for the function to be performed increase, the athletes cannot demonstrate appropriate movement pattern -as they are still internally focused-.[3]

Every healthy individual has a limited cognitive processing capacity, defined as 'attention', and each task demands a portion of this overall processing capacity.[4] If more than the total attention capacity is needed while performing two different cognitive/motor tasks simultaneously, the performance of one or both tasks may deteriorate.[5]

Learning of a performance progress from the cognitive level to the autonomous, from the declarative stage to procedural stage or from the controlled stage to the automatic one.[6-8] At the expert level, motor skills are generally believed to work "automatically" and require little conscious control.[9]

The dual task methodology, used to both monitor and improve the management of attention demands, is a testing and training model that requires a person to perform two tasks at the same time. The secondary task also acts as an external focus.

Under certain circumstances performance may become automatic, implying less involvement of attention and executive resources and less susceptibility to interference from a secondary task.[10] When this automation process is gained due to repetitions, less brain activation was found in expert/experienced athletes performing sports-related motor tasks than novice athletes.[11] This situation is called neural efficiency.[12] A person who demonstrates neural efficiency uses less of his attention for the relevant motor task than the novice. Thus, it is more effective if it responds adequately and accurately to future demands for additional attention and new tasks. In a dual task condition, the level of expertise in neural efficiency or motor skill has a significant impact. Especially considering that the motor learning process is restructured after injury, the managing such dual task conditions becomes even more critical in injured athletes.

However, many RTS (Return the Sport) processes mainly focus on the motor end of the sensorimotor system, and it has been reported that these tests may fail to detect athletes' biological, functional and psychological deficiencies.[13] Also, most RTS tests are performed in a predictable, stable, or closed environment. Additionally, most athletes are familiar with this type of testing.

Also, athletes may be aware of the criteria for performing these tests with an optimal quality of movement. This may lead to situations where clinicians evaluate the athlete's conscious, internally focused, and learned movement behaviour rather than his/her dynamic abilities concerning real game conditions. In support of the proposition, a study found that recovery athletes typically have an increased internal focus of attention.[14]

Unlike studies in the literature examining the potential changes in RTS test results in athletes with a dual task, in this study athletes with a history of only one side lower extremity injury were compared both between their legs and with healthy controls. This study aimed to examine the performance outcomes of athletes in the presence of an external focus. Therefore, functional hop tests were measured with a dual task. The study hypothesizes that athletes with a history of injury show a decrease in performance with dual task compared to healthy controls.

METHODS

Participants

Athletes (11 women, 28 men) who are still active in team sports that involve sudden physical changes of direction and jumps (basketball, volleyball, and football) were included in our study. Among the participants, 19 athletes (mean age; 19.05±3.71) with a history of unilateral lower extremity injury were examined under the previously injured group (PIG), and 20 athletes (mean age;16.95±1.39) without any previous lower extremity injury were examined under the control group (CG). Of the PIG athletes, 10 were basketball players, 4 were volleyball players and 5 were football players. Sixteen of these athletes are right-leg dominant, three are left-leg dominant. Of the CG athletes, 1 was a volleyball player and 19 were football players. Fifteen of these athletes were right-leg dominant and five were left-leg dominant. Demographic characteristics of the participants are shown in Table 1.

The inclusion criteria for this study were: the athlete had only one side initial or moderate lower extremity musculoskeletal injury before and having to stay away from sportive activities for at least one and at most six weeks in this one side injury history, and not having suffered a lower extremity injury for the last six months before the test was applied.

Exclusion criteria were: a history of bilateral lower extremity injuries, vestibular, respiratory and visual disorders, diabetes, auditory or cognitive deficits, use of drugs that affect balance, cognition and attention, pain in injured lower extremity (at least 2/10 according to VAS -Visual Analogue Scale), a history of lower extremity or spine surgery, a pathology or neurological disorders that may affect balance, head injury or symptoms related to head trauma were accepted.[15]

At the beginning of study, the ethics committee approval was obtained with the letter of Istanbul University Istanbul Medical Faculty Ethics Committee dated 21/04/2021 and numbered 182659, and the "Informed Consent Form" was signed by the participants and/or their parents before starting the measurements in line with the Declaration of Helsinki.

Pre-test period

Mini Mental State Test (MMSE) were administered to the participating athletes before starting their performance measurements. This assessment was used to determine the cognitive homogenization of the groups. The internal consistency of this scale was found to be moderate, and the test-retest reliability was high.[16]

For the cognitive task, one of the subtests of a short form of the fourth edition of the Wechsler intelligence scale (WAIS-IV) suggested by Ward, was used.[17] The backward digit span test of the WAIS-R was preferred.[18] Many authors have stated the reliability and validity of this scale.[19,20]

For the randomized number sequence to be used during dual task measurements to be of suitable difficulty for the cognitive level of the participant, a 2-digit randomized number sequence was first told once, as one digit per second, and he/she was asked to say the same number sequence in reverse. For each correct answer, the number of digits in the number sequence was increased by one. The number of digits in which the participant made a mistake was recorded and one more digit of this number was used during the measurements.

Functional tests

1- Triple hop for distance (THD): Athletes jumped as far as possible in 3 steps in a straight line from the starting point determined on the jumping ground, and the distance was measured and recorded.

2- Crossover hop for distance (CHD): Athletes jumped as far as possible by taking three consecutive diagonal steps to the medial-lateral-medial side of the line on the midline (width 15 cm) of the jumping floor. The distance reached by the athlete was measured and recorded.

3- 6-meter hop for timed (6MHT): Athletes jumped in one leg in the fastest way to the finish point, which is 6 meters away from the starting point marked on the jumping floor. The time elapsed from the start to the end of 6 meters was recorded with a stopwatch.

It has documented that this hop test is sensitive and specific for post-injury deficits[21], and reliability has been established for these tests by other authors.[22]

All hop tests were applied to both legs. Each test was performed three times (1 trial). The average of two measurements was taken. The test was repeated in cases where the athlete touches the ground with his/her other foot and/or his/her hand during jumping or landing, and incomplete or incorrect more than 50% of the number sequence in the cognitive task.

The athletes hop test performances were evaluated at two conditions for pre and post-test values. Firstly, the athletes were asked to do only the hop test without a cognitive task in the classical way. The results from this measurement formed the pre-test values. Then, for the dual task condition, they were asked to do the hop test together with the cognitive task. While applying the dual task, the previously determined randomized number sequence was told to the athlete at the starting line twice. After the second repetition, the athlete was asked to jump and keep the number in mind. At the end of the jump, the athlete was asked to say the previously given number sequence in reverse and recorded as he/she said it. The results from this measurement formed the post-test values. These pre- and post-test results were compared for comparison and interpretation of results.

Compound Hop Index (CHI) was used to prevent the significant difference between the height values of the groups affecting the jump test scores and to standardize the data. Therefore, the distance (m) reached by the athlete in the jump tests (THD and CHD) was divided by his/her own height (m).[23] The numerator and denominator values in the LSI calculation, as used and specified in this index, in order to use in comparisons of lower extremities of the groups; the worse performing extremity side with the extremity side with a history of injury, and the better performing extremity side with the extremity side without injury were matched.

Statistics analysis

Statistical analyses were processed using IBM SPSS Statistics, version 22.0 (Statistical Package for Social Sciences Inc.; Chicago, IL, USA). Shapiro Wilk test was used to evaluate the fit for normal distribution. It was found that the data showed normal distribution. Repeated measures ANOVA analysis were used for group comparisons of the variables. Paired sample T-test was used for before-after comparisons without group separation. $p<0.05$ was taken as statistical significance level. Cohen d effect sizes were calculated for interpretation of statistical results.

RESULTS

The demographic characteristics, cognitive task difficulty levels and MMSE scores of the athletes are given in Table 1.

The values of the hop distances in the THD and CHD measurements and the durations of the 6MHT measurements of the injured extremity side of the PIG group and the worse performing extremity side of the CG group are shown in Table 2.

Significant differences were found between the groups' THD, CHD, and 6MHT values during a single task (respectively, p=0.006; p=0.011; p=0.011). Significant differences were also found between the THD and CHD values of the groups during the dual task (respectively, p=0.014; p=0.007). CG achieved higher scores in all parameters in the table.

The values of the hop distances in the THD and CHD measurements and the durations of the 6MHT measurements of the non-injured extremity side of the PIG group and the better performing extremity side of the CG group are given in Table 3. Cohen-d values are given in Table 2 and Table 3.

Significant differences were found between the THD, CHD and 6MHT values of the groups during a single task (respectively, p=0.011; p=0.013; p=0.023). Significant differences were also found between the groups' THD, CHD, and 6MHT values during dual task (respectively, p=0.007; p=0.021; p=0.027). CG achieved higher scores in all parameters in the Table-2 and Table-3

DISCUSSION

The dual-task model we preferred in our study, directs the athlete's attention towards an external source. This allows us to observe and measure the unconscious movement patterns of the athlete. In this context, it was determined that compared to the CG group, the PIG group showed statistically significant lower jump performances on both the injured and the non-injured extremity sides in dual task conditions.

It is noteworthy that compared to CG athletes jumping ability, which is very important for many sports, lags in PIG athletes with a history of injury. This situation makes us think that although at least six months have passed since the athletes' injuries, some functional deficits may still be present, or the effect of an altered neuromuscular control that developed after the injury may be ongoing.

Among functional tests, hop tests are the most common assessments used to determine the return to play.[21] However, these hop tests

Table 1. Athletes' demographics, cognitive task difficulty levels, and Mini Mental State Examination (MMSE) scores.

	Previously Injured Group	Control Group	
	Mean±SD	Mean±SD	p
Height (m)	1.80±0.20	1.75±0.13	0.049*
Body weight (kg)	69.64±2.96	69.62±1.28	0.996
Body mass index (kg/m²)	21.12±0.55	22.66±0.52	0.050*
Cognitive task difficulty levels	6.53±1.02	6.30±0.80	0.375
Mini Mental State Examination score	28.84±0.68	29.35±0.74	0.071

*$p \leq 0.05$.

Table 2. Results of Previously Injured Group (PIG) injured extremity side and Control Group (CG) extremity side with worse performance score.

	Previously Injured Group	Control Group		
	Mean±SD	Mean±SD	p	Cohen's d
THD single task (m/m)	2.53±0.42	2.93±0.44	0.006*	0.933
THD dual task (m/m)	2.53±0.43	2.90±0.47	0.014*	0.828
CHD single task (m/m)	2.36±0.47	2.79±0.51	0.011*	0.861
CHD dual task (m/m)	2.36±0.43	2.77±0.46	0.007*	0.916
6MHT single task (sec)	2.64±0.33	2.37±0.01	0.011*	1.119
6MHT dual task (sec)	2.73±0.40	2.49±0.45	0.103	0.545

*$p<0.05$. THD: Triple Hop Distance. CHD: Crossover Hop Distance. 6MHT: 6 Meter Hop for Timed.

Table 3. Results of Previously Injured Group (PIG) injured extremity side and Control Group (CG) extremity side with better performance score.

	Previously Injured Group	Control Group		
	Mean±SD	Mean±SD	p	Cohen's d
THD single task (m/m)	2.56±0.44	2.95±0.45	0.011*	0.859
THD dual task (m/m)	2.54±0.44	2.96±0.48	0.007*	0.909
CHD single task (m/m)	2.35±0.52	2.75±0.44	0.013*	0.836
CHD dual task (m/m)	2.40±0.48	2.77±0.46	0.021*	0.773
6MHT single task (sec)	2.64±0.36	2.37±0.37	0.023*	0.716
6MHT dual task (sec)	2.75±0.40	2.46±0.37	0.027*	0.748

*$p<0.05$. THD: Triple Hop Distance. CHD: Crossover Hop Distance. 6MHT: 6 Meter Hop for Timed.

may not reveal the risk of injury related to neuro-cognitive deficits or the neurophysiological dysfunction that continues after injury.[24]

Because in these hop tests, athletes are aware of showing their 'best performance' and are used to these 'expected' jumps. Therefore, adding neurocognitive dimensions to these tests during measurements will help us obtain more realistic performance outcomes.

Therefore, it was emphasized that protocols for rehabilitation after sports injury should include not only classical physical manoeuvres associated with recovery and injury risk, but also cognitive challenges induced by reactive visuospatial stimuli, including the neuro-cognitive side of athletic performance.[25]

Supporting this idea, a study found that athletes who had undergone ACL reconstruction showed an altered neuromuscular response.[26] The reconstructed group was found to be less adaptable to perturbed tasks than healthy controls, possibly because of changing proprioceptive inputs. In addition to this claim, the reinvestment theory, which can occur after injury and, claims that people can impair physical performance by directing attention internally to movement control, we can think that our athletes in the PIG group still focus internally on their movement control. Therefore, they are insufficient to meet the possible attention demands.[27]

Also, in a study conducted in individuals with ligament injuries found that the cerebral structure of individuals with injury shows potentially maladaptive neuroplasticity, therefore the motor and premotor areas of the cortex are more active during simple movement tasks.[3] In other words, more brain activation was seen, just as in the early times of motor learning.

Even if PIG athletes have physically recovered from their injuries and can return to the athletic field, their altered cortical activation has likely led them to a dual-task intervention in dual-task situations. The capacity-sharing theory or the bottleneck theory explains this situtation.[28,29] Capacity-sharing theory assumes that attentional resources are limited and performing a particular task involves some of this limited information-processing capacity.[28-30] Therefore, it indicates that if two tasks are performed simultaneously that exceed one's processing capacity, the performance of one or both tasks will decrease. Also, the bottleneck theory assumes that the sources of attention are limited and only a certain amount of information can be processed at a time.[29] Therefore, when two tasks that require the same compute resources are performed simultaneously, one or both tasks will be delayed or corrupted, thus causing dual task interference.

In addition to these theories, Wulf, McNevin, and Shea proposed the constrained action hypothesis to explain the benefits of motor learning and performance often observed when physically performing individuals adopt an external focus compared to an internal focus of attention.[31] This hypothesis proposes that consciously directing attention internally interferes with automatic-that is, unconscious-processes of motor behaviour. This interruption in automatic processing restricts the motor program and causes the person's motor performance to decrease. In contrast, automatic control processes are facilitated when individuals concentrate on the effects of a movement-that is, external focus. This facilitation allows the motor control system to self-organize more naturally without overloading the central and peripheral nervous systems.

The dual-task model directs athlete's attention towards an external source of attention while performing a task. According to the action-restricted hypothesis, this attentional change may allow motor systems to operate automatically, resulting in more efficient performance.[31]

Studies explaining why the internal attention focus, one of the focus types used by the individual during a physical movement, causes a decrease in performance. According to one of the theories explaining this, attention is required in physical movements to control the performance of the task in the first stage of acquiring motor skills. As knowledge of the process accumulates through practice, performing the task automatically without conscious control becomes possible.[33]

The priority preferences of individuals during the task may also change due to altered cortical activation that develops with injury.[28,31,33] In our study, it is difficult to determine whether the athletes prioritize the cognitive or the motor task. However, a study in the literature indicated that it is possible for participants to choose to prioritize lesser-known cognitive tasks when presented with a more familiar motor task.[34]

The athletes of the PIG group might have prioritised the cognitive task that they are new to instead of paying attention to the jumping movement, which we think they were more familiar, and therefore might have shown poor physical performance during the dual task.

In addition, research on skill acquisition and automaticity has documented differences in the attention needs of novice and experienced skill performance. This suggests that the cognitive mechanisms governing task execution depend on the level of expertise.[35] It should also be considered that this neural efficiency observed in expert skill performers may affect the occurrence of dual-task intervention.

Limitations

Neurocognitive functions have many dimensions. However, in our study, kinematic test analyses could only be performed with the dual task method. It is also possible to add measures, including visual-motor and cognitive-motor function, to these tests. Neuro-muscular deficits do not only affect the injured extremity but also affect bilaterally. For this reason, pre-injury data of the athletes should be obtained to make more appropriate comments, and comparisons should be made accordingly. The branch distribution of the athletes in the groups was not homogeneous. Also, considering the effects of factors such as sleep and psychological state on cognitive performance, it should be noted that questionnaires that follow these variables can also be used.

Conclusion

As a result, the tests that will be preferred within the framework of cognitive and functional combinations for athletes can make valuable contributions providing a more comprehensive detection of deficits developing after injury. Therefore, we suggest that dual-task tests and studies related to their results will contribute to evaluations in the RTS process.

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