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ORIGINAL ARTICLE

Impact of reduced frame rate on kinematic analyses in videofluoroscopic swallowing studies

Videofloroskopik yutma çalışmalarında azaltılmış kare hızının kinematik analizlere etkisi

Ömer Faruk YAŞAROĞLU[1], Harun ÇİĞ[2], Numan DEMİR[3], Selen SEREL ARSLAN[3]

Abstract

Purpose: Videofluoroscopic Swallowing Study (VFSS) is considered the gold standard for evaluating swallowing physiology. However, as VFSS involves ionizing radiation, minimizing exposure is crucial. This study aimed to compare the accuracy of kinematic analyses performed at 25, 20, and 15 frames per second (fps) with those obtained at 30 fps.

Methods: Twenty-four healthy adults (13 women, 11 men; mean age 23.96 ± 3.59 years) without dysphagia and with T-EAT-10 scores <3 were included. VFSS recordings of dry swallow at 30 fps were retrospectively analyzed and downsampled to 25, 20, and 15 fps using MATLAB/Python. Superior and anterior hyoid displacements were measured with STAMPS software and compared across frame rates.

Results: Total hyoid displacement and superior hyoid displacement significantly differed by frame rate (p<0.001). Post-hoc tests showed significant differences between 30 fps and both 20 fps (p<0.001) and 15 fps (p<0.001), but no difference between 25 fps and 30 fps (p=0.075). Anterior hyoid displacement did not differ among frame rates (p=0.434).

Conclusion: Reducing the frame rate to 25 fps maintained the accuracy of total and superior hyoid displacement measurements, while lower frame rates (20 and 15 fps) reduced measurement accuracy. These findings suggest that 25 fps may be sufficient to assess hyoid kinematics while reducing radiation exposure. Since this study is limited to healthy adults and dry swallowing task, further studies including patients with dysphagia and bolus swallows are needed.

Keywords: Deglutition Disorders, Larynx, Radiation Protection

Öz

Amaç: *Videofloroskopik Yutma Çalışması (VFSS), yutma fizyolojisinin değerlendirilmesinde altın standart kabul edilmektedir. Ancak VFSS iyonizan radyasyon içerdiğinden, maruziyetin en aza indirilmesi önemlidir. Bu çalışmanın amacı, 25, 20 ve 15 kare/saniye (fps) hızında yapılan kinematik analizlerin doğruluğunu 30 fps ile karşılaştırmaktır.*

Yöntem: *Yutma bozukluğu olmayan ve T-EAT-10 puanı <3 olan 24 sağlıklı birey (13 kadın, 11 erkek; ort. yaş 23,96 ± 3,59 yıl) çalışmaya dahil edildi. Katılımcılardan elde edilen 30 fps kuru yutma VFSS kayıtları retrospektif olarak incelendi ve MATLAB/Python kullanılarak 25, 20 ve 15 fps'ye indirildi. Hyoid'in süperior ve anterior hareketleri STAMPS yazılımı ile ölçülerek karşılaştırıldı.*

Bulgular: *Toplam hyoid hareketi ve süperior hyoid hareketi kare hızına göre anlamlı farklılık gösterdi (p<0,001). Post-hoc analizlerinde 30 fps ile 20 fps (p<0,001) ve 15 fps (p<0,001) arasında anlamlı fark bulundu; ancak 25 fps ile 30 fps arasında fark yoktu (p=0,075). Anterior hyoid hareketi kare hızları arasında farklılık göstermedi (p=0,434).*

Sonuç: *Kare hızının 25 fps'ye düşürülmesi total ve süperior hyoid kinematik analizlerinin doğruluğunu korurken, daha düşük kare hızları (20 ve 15 fps) doğruluğu azaltmaktadır. Bu bulgular, 25 fps'nin hyoid kinematik değerlendirmesi için yeterli olabileceğini ve aynı zamanda radyasyon maruziyetinin azaltılmasını sağlayabileceğini göstermektedir. Bu çalışma sağlıklı bireyler ve kuru yutma görevleriyle sınırlı olduğu için yutma bozukluğu olan hastalarda ve bolus yutmayı içeren daha ileri çalışmalar gereklidir.*

Anahtar Kelimeler: *Yutma bozuklukları, Larenks, Radyasyondan korunma*

1:Harran University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Şanlıurfa, Türkiye
2:Harran University, Faculty of Engineering, Department of Software Engineering, Şanlıurfa, Türkiye
3:Hacettepe University, Faculty of Physical Therapy and Rehabilitation, Ankara, Türkiye
Corresponding Author:Ömer Faruk Yaşaroğlu : farukyasar13@gmail.com
ORCID IDs (order of authors): 0000-0002-1867-9950; 0000-0003-0419-9531; 0000-0001-6308-0237; 0000-0002-2463-7503
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INTRODUCTION

Swallowing is a complex sensorimotor activity consisting of oral, pharyngeal, and esophageal phases. Any problems occurring in one or more of these phases are referred to as dysphagia. Dysphagia is a clinical condition that may cause serious complications, including malnutrition, dehydration, and aspiration pneumonia as well as decreased quality of life.[1] One of the most widely used instrumental evaluation methods is Videofluoroscopic Swallowing Study (VFSS), which is considered as the gold standard assessment in dysphagia. This method enables the dynamical visualization of the passage of the bolus from the oral cavity to the esophagus for detailed analysis of the physiological components of swallowing function.[2] VFSS is used to assess swallowing safety and efficacy, and to measure temporal and spatial parameters of swallowing. In terms of temporal measures, oropharyngeal bolus transit time, laryngeal vestibule closure time and upper esophageal sphincter opening time can be measured. In addition, the extent of anterior and superior movement of the hyoid and larynx as spatial measures can also be evaluated. These analyses provide a detailed understanding of the physiology of swallowing function, the effectiveness of swallowing rehabilitation, and the impact of specific exercises or maneuvers on swallowing physiology.[3,4]

As VFSS involves ionizing radiation, minimizing radiation exposure is crucial for clinician and patient safety.[5] The ionizing radiation level of VFSS does not cause deterministic effects (e.g., skin burns); however, it may cause stochastic effects (e.g., cancer) since there is no definitive threshold for such effects.[6] Therefore, all radiographic studies, including VFSS, are conducted in accordance with the radiation safety principle of As Low As Reasonably Achievable (ALARA).[7] In the literature, radiation exposure can be reduced by shortening fluoroscopy duration, narrowing the imaging field, and using filters. Additionally, reducing the frame rate and pulse rate are also frequently used strategies to lower exposure.[5,6]

Modern digital fluoroscopy systems allow adjustment of two key parameters that determine image quality including pulse rate (number of X-ray pulses per second) and frame rate (number of images recorded per second). 30 pulses per second (pps) and 30 frames per second (fps) are generally recommended and are therefore used as the reference standard for optimum image quality. This ensures that each X-ray pulse corresponds to a single recorded frame, and thereby providing the highest temporal resolution for capturing rapid swallowing kinematics.[2,8] To minimize patient radiation exposure, pps or fps values are usually reduced. Modern devices often adjust to equalize for the other value when pps or fps is reduced.[9] Pulse rate (pps) is directly related to the X-ray output of the fluoroscopy system and determines the number of unique images produced per second which is essentially adjusted by the equipment.[10] In retrospective downsampling studies, the effects of pps reduction are often simulated by downsampling fps.[9,11] Therefore, although pps and fps are different technical parameters, they are often used interchangeably for methodological purposes to model reductions in temporal resolution. However, findings regarding the effect of reducing pps or fps are inconsistent. Lavly et al. reported that reducing the frame rate to 15 fps during pediatric VFSS effectively reduced radiation exposure without affecting diagnostic performance compared to 30 fps.[12] In contrast, another study showed that recordings at 15 pps and 5 pps significantly reduced the diagnostic accuracy and reliability of kinematic analyses compared to 30 pps.[11]

In accordance with the principle of minimizing radiation exposure in radiological studies, lowering fps or pps proportionally reduces radiation dose. However, there are concerns that a reduced frame rate may affect the accuracy of diagnostic and kinematic evaluations. One study reported that kinematic analysis of swallowing function was adversely affected at 15 and 5 fps.[11] To date, no studies have systematically examined the accuracy of kinematic analyses performed at mid-range frame rates between 15 and 30 fps. It is crucial to determine the optimal mid-range frame rate to balance accurate kinematic assessment and radiation safety during routine VFSS for clinical practice. The aim of this study is to compare the accuracy of swallowing kinematic analyses performed at 25 fps, 20 fps, and 15 fps with swallowing kinematic analyses obtained at 30 fps.

METHODS

Study Design

This study is a retrospective observational study which was conducted in collaboration between Hacettepe University and Harran University. VFSS records from the Swallowing Disorders Unit of the Faculty of Physical Therapy and Rehabilitation, Hacettepe University, between December 2022 and December 2024 were retrospectively reviewed. Ethical approval for the study protocol was obtained from the Ethics Committee of the same university (Approval no: FTREK25/115).

Participants

The study includes individuals who underwent VFSS due to subjective swallowing complaints at the Swallowing Disorders Unit between December 2022 and December 2024 but were not diagnosed with detectable dysphagia following a comprehensive evaluation.

The Turkish version of the Eating Assessment Tool-10 (T-EAT-10) was routinely administered to all patients admitted to the unit and documented in their medical records. All VFSS recordings were archived on secure hard drives and stored in locked cabinets. For this study, the T-EAT-10 scores and VFSS recordings were retrospectively reviewed.

Inclusion criteria were as follows;

- Being between 18–35 years of age,
- Having undergone VFSS between December 2022 and December 2024,
- Having VFSS recordings in the lateral position with high image quality (30 fps),
- Having VFSS recordings containing at least one complete swallowing cycle (oral phase – pharyngeal phase – esophageal entry),
- Not having any problem in swallowing function reported in the VFSS,
- Having a T-EAT-10 score below 3.

Exclusion Criteria

- Having disc herniation, mechanical neck pain, or any pathology in the cervical region,
- Having a temporomandibular joint problem that may affect joint biomechanics and muscle function,
- Having any neurological or systemic disease,
- Having undergone surgery or radiotherapy in the head and neck region,
- Having insufficient image quality or significant motion artifacts in VFSS recording,
- Having unclear anatomical landmarks that prevent reliable frame-by-frame tracking in VFSS recording.

Assessments

For participants who met the inclusion criteria, demographic data (age, gender) obtained from patient files, T-EAT-10 scores, and lateral view VFSS recordings at 30 fps containing at least one complete swallowing cycle were examined.

Turkish Eating Assessment Tool-10 (T-EAT-10)

The T-EAT-10 is a Likert-type questionnaire consisting of 10 questions that assesses the severity of dysphagia symptoms in adults. Each question is scored from 0 to 4. “0” means no problem, while “4” means severe problem. A score of 3 or higher suggests the presence of dysphagia, while a score of 15 or higher suggests aspiration.[13] Its validity and reliability in Turkish were established by Demir N. et al.[14]

Videofluoroscopic Swallowing Study (VFSS)

VFSS is the gold standard method for examining swallowing physiology. Using a fluoroscopy device, lateral plane images were obtained while the participants were in a sitting position. A frame rate of 30 fps was used to ensure that no moment of hyoid movement was missed.[2] For kinematic analysis, a 17 mm coin was attached to the participants’ mastoid process, which allowed the pixel-based displacement measured in VFSS to be converted into millimeters.[4] To observe hyolaryngeal movement, participants were asked to perform dry swallows without food. Subsequently, swallowing safety and efficiency were evaluated using water mixed with a radio-opaque material, yogurt, and biscuits, respectively. In this study, only dry swallowing data from individuals without dysphagia were analyzed.

Reducing the Frames Per Second (fps)

The initial VFSS were recorded at 30 fps. The fps value was reduced by downsampling the original 30 fps videos. This was achieved using custom MATLAB/Python code. To obtain the specified fps values (25, 20, 15 fps), new video series were created by systematically deleting frames at predetermined intervals. For example, to reduce to 15 fps, every other frame was deleted, and for 20 fps, every third frame was deleted. This approach reduced the number of unique frames available for analysis while maintaining the total video duration.[9,11] Thus, although the temporal resolution of the images was reduced, comparability in the analysis was maintained without any additional radiation exposure for patients. However, this downsampling method does not fully reflect the true conditions of low-frame-rate fluoroscopy, as physical acquisition effects (e.g., motion blur) cannot be retrospectively reproduced. Accordingly, the findings primarily reflect the effect of reduced temporal sampling on kinematic measurements.

Kinematic analyses

Kinematic analyses were performed on videos recorded at 30, 25, 20, and 15 fps to evaluate the superior (y coordinate) and anterior (x coordinate) hyoid movements. The analyses utilized STAMPS (Spatio-Temporal Analyzer for Motion and Physiologic Study), an open-access software developed based on MATLAB. This software was developed to acquire, process, and analyze swallowing-related motion data. Its user-friendly interface allows researchers with no programming background to easily conduct analyses and generate various graphical outputs. All analyses were performed by a single trained rater. The rater was not blinded to the frame rate conditions during analysis. Study-specific intra- or inter-rater reliability was not assessed; however, the inter-rater and intra-rater reliability of the STAMPS software in measuring hyolaryngeal movement has been reported to be quite high.[15,16] For each image, reference points were marked to create a coordinate system. The anterior-inferior point of the C4 vertebra was defined as the origin. A vertical line from C4 to the anterior-inferior point of C2 represented the y coordinate, while a horizontal line drawn perpendicular to it on the left side of C4 represented the x coordinate. In addition, the anterior-inferior point of the hyoid bone was marked. This coordinate system was based on methods recommended in the literature for kinematic analyses.[4,17] (Figure 1). To measure superior and anterior hyoid movement, the maximum coordinate during hyoid elevation was subtracted from the starting coordinate. The movement was calculated as (maximum coordinate – starting coordinate) for superior and anterior positions separately. Thus, in each frame, the position of the hyoid relative to C4 was determined and the amount of movement was calculated in pixels. The total hyoid movement was determined by calculating the hypotenuse of the superior and anterior hyoid movements. To convert the pixel values into millimeters, a 17 mm coin attached to the mastoid process during VFSS was used as a reference. The diameter of the coin in the image was measured in pixels using the software and compared with its actual diameter, thereby calculating the millimeter value corresponding to each pixel. This method ensured that the participant's head movement back and forth or changes in distance from the device did not affect the measurement accuracy.[18,19] Finally, superior and anterior hyoid movements during dry swallowing were recorded in millimeters. For each participant, kinematic measurements were obtained from a single dry swallow. Values obtained at 15, 20, and 25 fps were then compared with values obtained at 30 fps.

Statistical analysis

Sample size calculation was performed using G*Power 3.1 software. Based on a previous similar study, the effect size was determined as $f = 0.25$ (medium), significance level as $\alpha = 0.05$, test power ($1-\beta$) as 80%, number of measurements as 4, and the correlation between repeated measures as 0.5.[11] According to these parameters, data from 24 participants were included in the study.

Statistical analyses were performed using SPSS version 25 (SPSS Inc., Chicago, IL, USA). The normality of the distribution for quantitative variables was assessed through skewness and kurtosis statistics. Values with an absolute skewness less than ±2.0 and a kurtosis below 7.0 were considered to indicate a normal distribution.[20] All data were found to be normally distributed. Data were presented as mean ± standard deviation. To analyze whether there was a significant difference in hyoid movement across different fps values, a repeated-measures analysis of variance (ANOVA) was performed. A p-value of less than 0.05 was considered statistically significant. For post-hoc analyses, Bonferroni correction was applied for multiple comparisons (adjusted significance level: 0.05/6 = 0.0083).

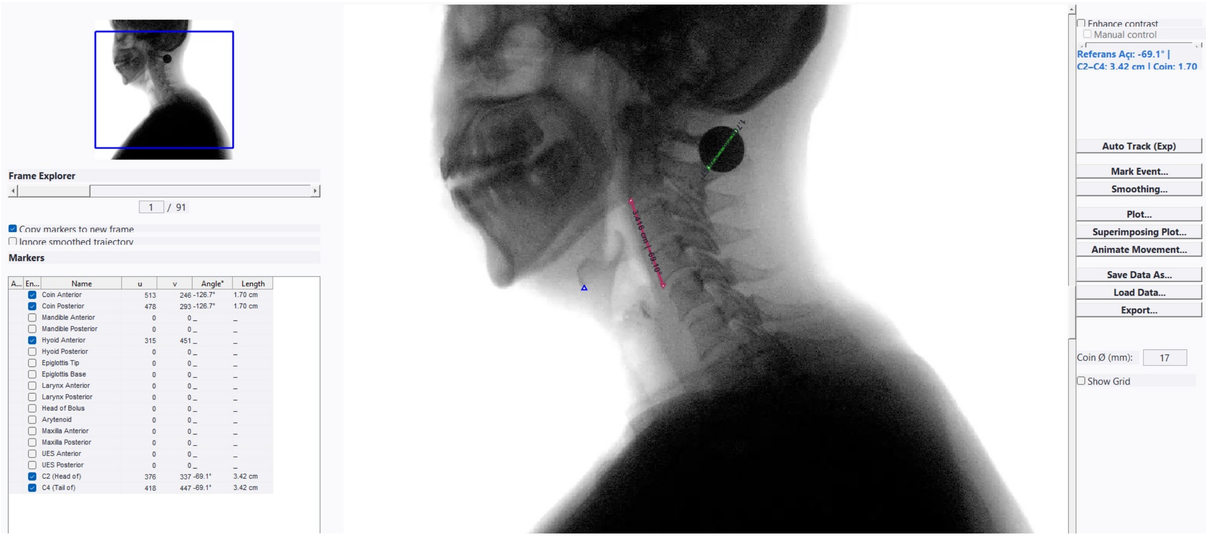

Figure 1: Kinematic analysis of hyoid movement during normal swallowing using STAMPS. Anatomical Scalar: 1: anterior-inferior portion of hyoid; 2: anterior-inferior portion of C2; 3: anterior-inferior portion of C4.

RESULTS

A total of 24 participants were included in the study: 13 females (22.85 ± 2.79 years) and 11 males (25.27 ± 4.10 years). The overall mean age was 23.96 ± 3.59 years.

Mean superior and anterior hyoid movement for each frame rate is presented in Table 1.

A significant difference was found in the superior hyoid movement across frame rates ($p<0.001$, $\eta^2=0.318$). Post-hoc analyses revealed that hyoid movement at 30 fps was significantly greater compared to 15 fps ($p<0.001$) and 20 fps ($p=0.003$), whereas no significant difference was observed between 30 fps and 25 fps ($p>0.05$) (Table 2). The linear trend test was also significant ($p<0.001$, $\eta^2=0.507$), indicating that superior hyoid movement increased linearly with higher frame rates.

No significant difference was found in anterior hyoid movement across frame rates ($p=0.434$, $\eta^2=0.039$). Both linear and quadratic trend tests were also non-significant ($p>0.05$). Total hyoid movement was found significantly different across frame rates ($p < 0.001$, $\eta^2 = 0.340$). Post-hoc pairwise comparisons with Bonferroni adjustment revealed that hyoid movement at 30 fps was significantly greater than at 20 fps ($p < 0.001$) and 15 fps ($p < 0.001$). No statistically significant difference was observed between 30 fps and 25 fps ($p > 0.05$) (Table 3). The linear trend analysis was also significant ($p<0.001$, $\eta^2=0.524$), suggesting a linear increase in total hyoid movement as the frame rate increased.

DISCUSSION

The aim of this study was to investigate the effect of reducing the frame rate to 25, 20, and 15 fps on the accuracy of kinematic analysis of swallowing in VFSS. The findings revealed that the superior hyoid movement decreased as the frame rate decreased. This decrease was significant at 20 fps and 15 fps compared to 30 fps while no difference was observed in the anterior hyoid movement at different frame rates.

In this study, it was found that total hyoid movement decreased linearly as the frame rate was reduced. However, these decreases reached statistical significance only between 30 fps and 20 fps and between 30 fps and 15 fps. The effect of reducing the frame rate in VFSS is still controversial in the literature. Lavly et al. reported that reducing the frame rate from 30 fps to 15 fps in pediatric VFSS provided comparable diagnostic performance for penetration and aspiration, with high

Table 1. Comparison of hyoid movement at different frame rates.

Frame Rate (fps)	Hyoid movement (mm)		
	Superior (X±SD)	Anterior (X±SD)	Total (X±SD)
15 (n=24)	10.99±4.20	6.85±2.34	13.28±3.72
20 (n=24)	11.40±4.04	7.00±2.40	13.67±3.71
25 (n=24)	11.74±3.94	6.96±2.38	13.92±3.63
30 (n=24)	12.13±4.18	7.10±2.21	14.32±3.77

fps: frame per second.

Table 2. Pairwise comparisons of superior hyoid movement across frame rates.

Frame Rate	Mean diff. (mm)	Std. Error	95%CI Lower	95%CI Upper	p	Cohen's d
30 fps-25 fps	0.382	0.152	-0.058	0.822	0.118	0.51
30 fps-20 fps	0.723	0.178	0.21	1.235	0.003*	0.83
30 fps-15 fps	1.141	0.23	0.477	1.805	<0.001*	1.01
25 fps-20 fps	0.341	0.159	-0.119	0.800	0.261	0.44
25 fps-15 fps	0.758	0.278	-0.044	1.561	0.072	0.56
20 fps-15 fps	0.418	0.232	-0.252	1.088	0.508	0.37

fps: frame per second; CI: Confidence Interval *Repeated-measures ANOVA with Bonferroni-adjusted p-values; p<0.05.

Table 3. Pairwise comparisons of total hyoid movement across frame rates.

Frame Rate	Mean diff. (mm)	Std. Error	95%CI Lower	95%CI Upper	p	Cohen's d
30 fps-25 fps	0.401	0.148	-0.026	0.828	0.075	0.55
30 fps-20 fps	0.654	0.137	0.258	1.049	<0.001*	0.97
30 fps-15 fps	1.045	0.206	0.450	1.639	<0.001*	1.04
25 fps-20 fps	0.253	0.141	-0.153	0.685	0.513	0.37
25 fps-15 fps	0.643	0.237	-0.040	1.327	0.073	0.55
20 fps-15 fps	0.391	0.189	-0.155	0.937	0.302	0.42

fps: frame per second; CI: Confidence Interval *Repeated-measures ANOVA with Bonferroni-adjusted p-values; p<0.05

sensitivity (93%) and specificity (98%).[12] In contrast, studies conducted in adults have shown that reducing the pulse rate below 30 pps significantly compromises diagnostic accuracy and affects Modified Barium Swallow Study Impairment Profile (MBSImP) and Penetration-Aspiration Scale (PAS) scores.[9,21] One study in the literature specifically examined the effect of reducing the frame or pulse rate on kinematic analyses. Palmer et al. investigated the effect on kinematic analyses by reducing 30 pps recordings to 15 and 5 pps and reported significant reduced precision at the peak hyoid position at 15 and 5 pps. It was also stated that these changes were unpredictable and could alter clinical observations and treatment recommendations.[11] The results of our study are fully consistent with these findings. Unlike the previous study, this study also analyzed intermediate values of 20 and 25 fps. According to our findings, reducing the frame rate to 25 fps did not affect the accuracy of the kinematic analysis of swallowing function. In a clinical perspective, these findings indicate that 25 fps can be used without the risk of misinterpreting hyoid movements. In contrast, reducing the frame rate to 20 fps or 15 fps increased the likelihood of underestimating superior hyoid movement, which may result in misdiagnosis or inappropriate treatment recommendations. Thus, while accuracy appears to be preserved at 25 fps, it should be remembered to be careful when using lower frame rates.

The radiation dose received by the patients during standard VFSS is relatively low (0.2–0.85 mSv).[22] However, the two most radiosensitive organs in the body including the lens and thyroid are typically in the radiation field. Therefore, it is recommended that radiation exposure should be minimized in accordance with the ALARA principle.[23] An important implication of our findings is that using 25 fps not only maintains the accuracy of kinematic analyses but may also contribute to reducing radiation exposure. These features highlight 25 fps as a potentially safer and clinically feasible option. Nevertheless, further research is warranted to examine the impact of reducing the frame rate to 25 fps on diagnostic accuracy.

Using a lower fps reduces the number of frames that capture peak hyoid movement, potentially leading to measurement underestimation. The current study shows that there was a decline in superior hyoid movement with reduced frame rates. However, this decrease was not found to be significant at 25 fps. The anterior hyoid movement did not show a significant difference at different frame rates. This may be related to the movement characteristics of the hyoid. The superior hyoid movement requires a greater distance than the anterior movement.[4,24] Superior hyoid movement occurs very rapidly and reaches its peak within a narrow timeframe. In contrast, anterior movement having a longer duration increases the likelihood of reaching the peak even at lower fps.[25] This may explain why no significant difference was observed in the x-axis in our study. Furthermore, Zhang et al. reported that only the anterior movement of the hyoid bone was a significant and strong predictor of penetration/aspiration risk.[26] In our study, no significant measurement loss was observed on the x-axis. This is clinically important, as reliable assessment of anterior hyoid movement even at lower fps can support accurate prediction of penetration/aspiration risk. However, superior hyoid movement is primarily related to oral phase dynamics such as food consistency and swallowing sequence.[27] Underestimating superior hyoid movement at low frame rates should be avoided, as this may directly compromise the accuracy of clinical assessments.

In our study, compared to 30 fps, superior hyoid movement decreased by 6% at 20 fps and 9.4% at 15 fps, while total hyoid displacement decreased by 4.5% at 20 fps and 7.3% at 15 fps. These differences were significant, and the corresponding effect sizes ranged from moderate to large, indicating that frame rate has a measurable effect on kinematic outcomes. During clinical observation, minimal hyolaryngeal movement may indicate insufficient deviation of airway entry from bolus flow, which may raise clinical concerns regarding swallowing safety.[11] However, one study in the patients with dysphagia reported that a 15.1% decrease in hyoid movement was a critical threshold for compromised swallowing safety.[28] The decreases observed in our study may reduce measurement accuracy but may not pose a clinically significant risk to swallowing safety. Further studies in patients with dysphagia are needed to more comprehensively evaluate the clinical significance of these findings.

Everton et al. reported that digital VFSS recordings collected from 17 hospitals in five different countries were obtained at different frame rates, but only recordings with ≥ 25 fps were included for temporal and clearance measurements.[29] The study stated that the selection of ≥ 25 fps was made to provide sufficient resolution for timing and kinematic measurements. However, this selection does not appear to be based on any analysis and may reflect the authors' subjective preference. The findings of our study partially support this ≥ 25 fps preference, as no significant change was observed in total hyoid movement at 25 fps compared to 30 fps. Nevertheless, the pulse and frame rate settings of fluoroscopy devices used in VFSS are generally 30 fps, 15 fps, 7.5 fps, and 3 fps.[23] Our results suggest that fluoroscopy devices with more precise fps or pps settings may be more useful.

Limitations

This study on normal swallowing provides a physiological baseline that serves as a normative reference for future clinical research. Nevertheless, the study has some limitations. First, the reduced frame rates were simulated through retrospective downsampling of videos originally acquired at 30 fps. This approach does not fully replicate true low–frame rate fluoroscopy conditions. Second, the inclusion of only healthy individuals performing dry swallows limits the generalizability of the findings. Dysphagia, aging, and the presence of a bolus are known to alter swallowing kinematics and may respond differently to reductions in temporal resolution.[30,31] Finally, although the reliability of the STAMPS software has been previously established, rater reliability was not specifically assessed for the current dataset. Therefore, further studies including dysphagic populations, geriatric individuals, bolus swallows, and study-specific reliability analyses are warranted.

Conclusion

This study is one of the first study to examine the effect of reducing the frame rate in VFSS from 30 fps to 25, 20, and 15 fps on the accuracy of kinematic analysis. Our findings indicate that reducing the frame rate to 25 fps does not significantly affect accuracy of kinematic analysis. In contrast, a significant decrease in superior hyoid movement was observed at 20 and 15 fps. No difference was found between frames in anterior hyoid movement. These results suggest that reducing the frame rate to 25 fps during VFSS may be a clinically feasible option for lowering radiation exposure in accordance with the ALARA principle while preserving the accuracy of kinematic analyses. Future studies should investigate the diagnostic accuracy of 25 fps in diverse clinical populations, including dysphagic and geriatric patients.

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Funding: *None*

Conflicts of Interest: *None*

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