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ORIGINAL RESEARCH

Reliability, validity and minimal detectable change of the quadriceps angle assessment in patients with knee osteoarthritis

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Abstract

Knee osteoarthritis (OA) is a multifaceted degenerative disease characterized by knee alignment alterations that impact the amplitude of the quadriceps angle (Q-angle). Q-angle is a diagnostic measure of knee alignment, and an indicator of the load distribution of patellofemoral and tibiofemoral joints. However, accurate assessment of this parameter necessitates the implementation of standardized and reliable measures to ensure methodological reproducibility. Thus, this study aimed to examine the concurrent validity, reliability, and minimal detectable change (MDC) of the Q-angle in patients with knee osteoarthritis (OA). The intra-rater and inter-rater reliabilities of each goniometric measurement were determined with the use of intraclass correlations (ICCs). The correlations between goniometric (clinical) and radiography (gold standard) measurements of Q-angle were assessed for concurrent validity. The intra-rater reliabilities of goniometric assessments in the supine and standing positions of the Q-angle were 0.90 and 0.96, respectively. The standard error of measurement (SEM) and minimal detectable change (MDC95) were 1.18 and 3.27 degrees for supine assessment and 0.87 and 2.40 degrees for standing assessment, respectively. The inter-rater reliabilities of goniometric assessments of the supine and standing position of the Q-angle were 0.86 and 0.92, respectively. SEM and MDC95 values were 1.59 and 4.39 degrees for supine assessment and 1.19 and 3.28 degrees for standing assessment, respectively. The radiographic measure showed a strong correlation with supine goniometric assessment ($p<0.05$, r: 0.777) and a significantly excellent correlation with standing goniometric assessment ($p<0.05$, r: 0.878). According to the findings of the current study, the goniometric measurement for the Q-angle is a valid and reliable method in patients with knee OA. Also, our results suggest that the goniometric measurement, as an inexpensive and radiation-free alternative, can be used to assess the Q-angle as accurately as radiography, in clinical practice.

Introduction

Knee osteoarthritis (OA) is a common joint disorder, particularly among elderly people. The disease leads to increased pain, limited range of motion, muscle weakness, degenerative changes of joint structure, and eventually functional disability (Sharma, 2021). Many different risk factors that contribute to knee OA have been suggested. Although aging, obesity, previous knee injury, and repetitive kneeling activities are all associated with knee OA; however, lower extremity malalignment is a key predisposing factor for the initiation and progression of OA (Driban et al., 2020; Lim et al., 2008). Thus, routine and objective monitoring of knee alignment in this population allows clinicians to determine biomechanical changes and to design rehabilitative and preventative interventions for knee OA.

The quadriceps angle (Q-angle), which is formed by the intersection of the lines of the pull of the quadriceps muscle and the patellar tendon, is one of the few measures of knee alignment, and is routinely

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assessed by physiotherapists and orthopedists in clinical settings (Örtqvist et al., 2011; Smith et al., 2008). The malalignment of the knee joint, including genu varus and valgus, namely alteration in Q-angle, directly alters the load distribution and disrupts the quadriceps muscle functioning (Hunter et al., 2009; Lim et al., 2008). Therefore, changes in the Q-angle have been linked to disorders such as knee joint cartilage erosion, femoral internal rotation, and internal tibial torsion. Furthermore, abnormality in the Q-angle leads to the weakening of the quadriceps muscle, which is the primary determinant of knee functions and overall functional level. The aforementioned conditions predispose the knee joint structures to degenerative changes and, eventually, progression of the knee OA (Almeida et al., 2016; Devan et al., 2004). Thus, clinically, determining the Q-angle, which is a significant component of physical examination, assists clinicians in more accurately selecting therapeutic interventions for patients with knee OA (Hunter et al., 2009).

Some techniques are available for measuring the Q-angle, such as radiography, computed tomography, and goniometric measure (Chevidikunnan et al., 2015; Smith et al., 2008). The goniometric measure is a simple, portable, and non-invasive technique to assess Q-angle, not requiring sophisticated radiographic equipment (Chevidikunnan et al., 2015; Merchant et al., 2020; Rahimi et al., 2012). The validity and reliability of the goniometric measure of Q-angle are reported in individuals with various conditions, such as healthy subjects and patients with acute knee pain (Chevidikunnan et al., 2015; Draper et al., 2011; Shultz et al., 2006; Weiss et al., 2013). Nonetheless, according to our best knowledge, no study investigated the validity and reliability of goniometric measure of Q-angle in patients with knee OA in the existing literature, even though it is previously used in numerous studies conducted on knee OA to determine knee alignment (Ekim et al., 2017; Vassão et al., 2020). Therefore, this study aimed to assess the goniometric measure of the Q-angle in patients with knee OA in terms of the intra- and inter-rater reliabilities, and minimal detectable change (MDC), and concurrent validity with the radiographic measure.

Methods

Participants

Fifty-two patients with the diagnosis of knee OA were enrolled in this study. Inclusion criteria were that patients had a diagnosis of knee OA according to the classification criteria of Kellgren and Lawrence, and able to understand the measure instructions, and were 30 years or above. Patients were excluded if they had a history of knee surgery, trauma, and rheumatic disease that may cause secondary knee OA, had a history of an orthopedic or neurological disorder that limited standing and walking ability, had a body-mass index (BMI) of ≥40 kg/m^2 to avoid any problem associated with the identifying of anatomical landmarks. An a priori power analysis indicated that a sample size of 48 subjects was sufficient in the reliability analysis to achieve 0.90 statistical power of intraclass correlations (ICCs) with a lower confidence interval (CI) of ICC=0.70 (Walter et al., 1998).

This study received ethical approval from the Dokuz Eylül University of Medical Ethics Committee (approval number: 2401-GOA). In the current study, informed consent was obtained prior to enrollment from all participants, according to the Declaration of Helsinki.

Procedure

Demographic characteristics of the patients with knee OA were obtained. The clinical assessment of the Q-angle was conducted by two examiners (one physiotherapist and one orthopedist) using a standard long-arm goniometer with one-degree accuracy. They had more than eight years of clinical experience in clinical assessment of patients and in orthopedic rehabilitation. Examiners were blinded to the assessment values that were obtained by the previous examiner. The anatomical landmarks identified before the assessment were erased by the examiner immediately following the assessment to avoid any influence on reliability measurement. The subjects were repositioned in between each assessment.

Goniometric Measure of Q-Angle

The goniometric measures of the Q-angle were performed in two different positions (supine and standing) for all subjects, according to a standardized protocol (Örtqvist et al., 2011). The two assessment methods of the Q-angle were performed in a random order. For the supine position assessment of the Q-angle, patients were placed in the supine position at the examination table with quadriceps relaxed, hip and knee extended, and lower extremity in a neutral position. After the testing position was aligned, the examiner identified the three anatomical landmarks (tibial tuberosity, the center of the patella and anterior superior iliac spine (ASIS)) by using inspection and palpation, and then labeled these landmarks. The goniometer axis was placed over the center of the patella with one arm in the ASIS direction, and the other arm in the tibial tuberosity center direction. For the standing position assessment of the Q-angle, the subjects were then instructed to stand in a comfortable and relaxed position with no obvious contraction of their quadriceps, and with their weight evenly distributed on both lower extremities aligned in a neutral position. The anatomical landmarks were redefined and labeled for this position. Then, the goniometer was repositioned as previously described for the supine position assessment, and the Q-angle was measured.

Patients were assessed twice by two independent investigators (physiotherapist and orthopedist) with an interval of 10 minutes to assess the inter-rater reliability. For intra-rater reliability, patients were measured for the two assessment methods of the Q-angle by the same investigator on two occasions at one-hour intervals. To avoid examiner bias and any possible confounding effect, the examiner was blinded to the other's measurements, the anatomical landmarks were erased immediately following assessments, and distinct forms were used. All assessments were performed in the same clinical setting to eliminate any confounding effect.

Radiographic Measure of Q-Angle

The Q-angle was measured using the full-limb anteroposterior radiograph of the lower extremities, which was taken in a weight-bearing position with full extension knee, relaxed quadriceps muscle, and bare feet aligned in a parallel position (Abdullah & Rajasekaran, 2022). The anatomic landmarks (the tibial tubercle, the midpoint of the patella and the ASIS) were identified on the radiographic image by an independent, experienced and blinded investigator. The intersection of the line connecting the center of the patella and the ASIS with the line connecting the tibial tuberosity and the center of the patella was recorded as the Q-angle.

Statistical Analysis

The data was analyzed using the IBM® SPSS® (ver. 26.0; IBM Corp., Armonk, NY, USA) package program for Windows software. The Kolmogorov-Smirnov normality test was used to determine the distribution of the data. The intra- and inter-rater reliabilities were calculated by ICCs, which determine the internal consistency between two measures. A coefficient value was defined as (<0.5) poor, (0.51 to 0.75) moderate, and (>0.75) excellent (Shrout & Fleiss, 1979). The accuracy of the measurement method was determined by calculating the standard error of measurement (SEM). The minimal detectable changes at the 95% confidence level (MDC_{95}) were calculated using the formula $MDC_{95}=SEM\times1.95\times\sqrt{2}$.

The correlation coefficient between the radiographic and the goniometric assessments was calculated using the Pearson's correlation to determine the concurrent validity of the goniometric Q-angle measurement. The correlation coefficient level was considered unacceptable if the coefficient was less than 0 and 0.49, moderate if it was between 0.50 and 0.69, strong if it was between 0.70–0.79, and excellent if it was between 0.80–1.00 (Lee Rodgers & Nicewander, 1988). A value of $p<0.05$ was set as statistically significant.

Results

No adverse events or complications were developed in participants during tests. Fifty-two patients [female: 46 (%88.5), male: 6 (%11.5)] with knee OA were included in this study. Patients' demographic and clinical characteristics are presented in Table 1.

Table 1
The demographics and characteristics (n=52).

Variables	Mean ± SD
Age	67.63 ± 8.35
Height (cm)	157.36 ± 7.01
Weight (kg)	80.78 ± 13.33
Body mass index (kg/m^2)	32.63 ± 4.90
Radiographic level of OA	**n (%)**
Stage-1	-
Stage-2	-
Stage-3	15 (28.8)
Stage-4	37 (71.2)

SD: Standard deviation; cm: centimeter; kg: kilogram; OA: Osteoarthritis.

Goniometric measures (supine and standing) of the Q-angle showed excellent intra-rater and inter-rater reliabilities. The intra-rater reliabilities of the goniometric Q-angle measurements in supine and standing were 0.90 and 0.96, respectively. The inter-rater reliabilities of the goniometric Q-angle measurements in supine and standing were 0.86 and 0.92, respectively. SEM and MDC_{95} of goniometric measure for both in supine and standing positions ranged from 0.87 to 4.39 degrees (see Table 2).

Table 2
The inter- and intra-examiner reliabilities of Q-angle in patients with knee OA.

Inter-Examiner	Rater 1 (PT)	Rater 2 (OS)	ICC (95% CI)	SEM	MDC_{95}
StQA (deg)	12.40 ± 4.41	12.96 ± 4.21	0.92 (0.86 to 0.95)	1.19	3.28
SuQA (deg)	14.03 ± 4.89	15.13 ± 4.26	0.86 (0.74 to 0.92)	1.59	4.39
Intra-Examiner	First Trial	Second Trial	ICC (95% CI)	SEM	MDC_{95}
StQA (deg)	12.40 ± 4.41	12.34 ± 4.36	0.96 (0.94 to 0.98)	0.87	2.40
SuQA (deg)	14.03 ± 4.89	12.65 ± 3.75	0.90 (0.74 to 0.95)	1.18	3.27

Q-angle: Quadriceps angle; OA: Osteoarthritis; ICC: Intra-class correlation coefficient, CI: confidence interval, SEM: standard error of measurement with a 95% confidence interval, MDC_{95}: Minimal Detectable Change at the 95% confidence level. StQA: Standing Q-Angle measure; SuQA: Supine Q-Angle measure; deg.: degrees, PT: Physiotherapist, OS: Orthopedic surgeon.

Table 3
Correlation between goniometric and radiographic measurement of the Q-angle.

Variables	Radiographic (r)	SuQA (r)
StQA	0.878***	0.895***
SuQA	0.777***	1

**0.01 < p ≤ 0.0;, **0.001 < p ≤ 0.01; ***p ≤ 0.001; r: Pearson's correlation coefficient for results; StQA: Standing Q-Angle measure; SuQA: Supine Q-Angle measure.*

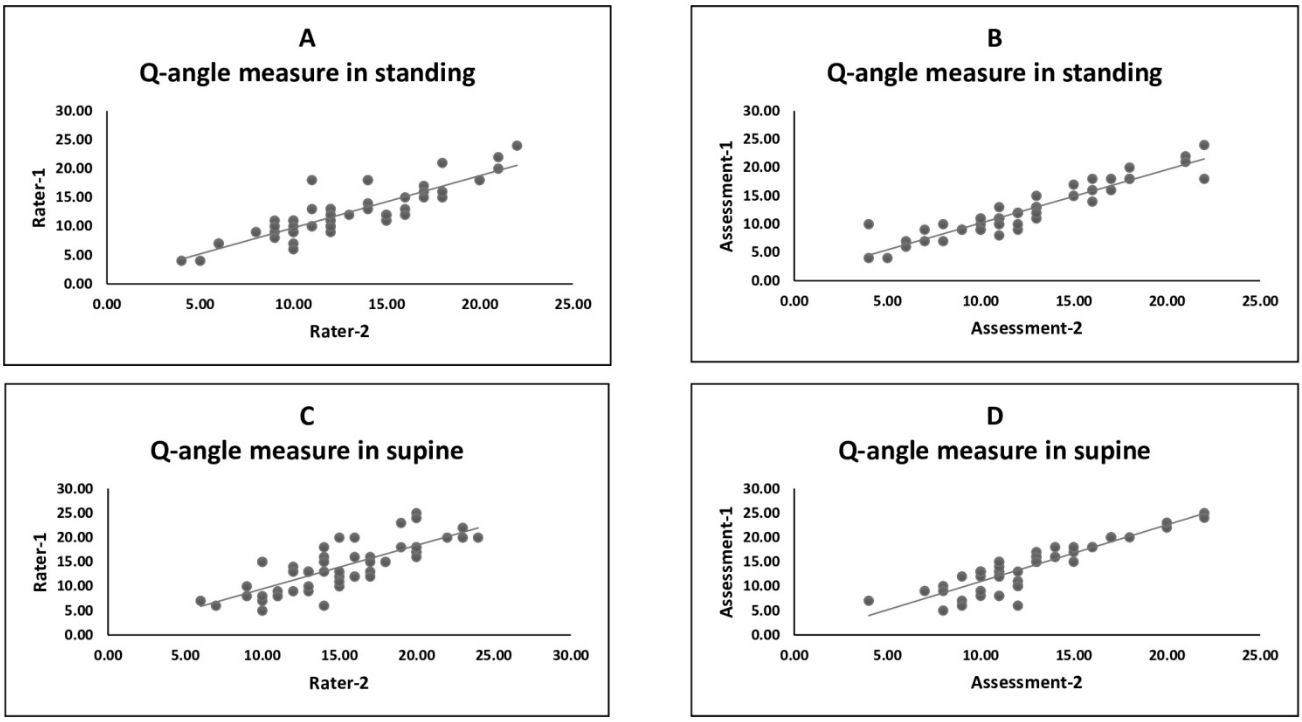

Figure 1: Plots showing the distributions of Q-angle of patients. A, Inter-examiner of Q-angle measure in standing. B, Intra-examiner of Q-angle measure in standing. C, Inter-examiner of Q-angle measure in supine. D, Intra-examiner of Q-angle measure in supine.

The goniometric measure in the supine position showed a strong correlation with the radiographic measure ($p<0.05$; r: 0.777), and the goniometric measure in the standing position showed an excellent correlation with the radiographic measure ($p<0.05$; r: 0.878). The validity and reliability findings of the Q-angle measurement are presented in Table 2 and Table 3. The distribution plot of Q-angle degrees between patients is shown in Figure 1.

Discussion

To the best of our knowledge, this is the first study to determine the intra- and inter-rater reliabilities, concurrent validity, SEM and MDC_{95} for the Q-angle assessment using a goniometer in patients with knee osteoarthritis. Our results showed goniometric measure of the Q-angle is a reliable and valid method in patients with knee OA. Our findings corroborate those of the previous studies that found the ICCs between 0.78 and 0.98 for goniometer-based Q-angle measures in different populations, such as asymptomatic subjects (Draper et al., 2011; Shultz et al., 2006; Weiss et al., 2013). However, these previous studies investigated the reliability of the goniometric measure of Q-angle using different methods (i.e., with a contracted or relaxed quadriceps) and equipment (i.e., short or long arm goniometer). Nevertheless, similar-level ICCs suggest that the goniometric measure is considerably reliable for assessing Q-angle, regardless of these differences.

Some alternative methods, such as radiography, computed tomography, and goniometric measures, are used for measuring Q-angle in the clinical setting (Chevidikunnan et al., 2015; Smith et al., 2008). Radiographic assessment is shown as a "gold standard" in the Q-angle assessment, and a slight angular change in the Q-angle can be detected by this method (Smith et al., 2008). Nonetheless, it is clinically impractical due to its non-portable, expensive, radiation-exposure, and sophisticated nature. Conversely, the goniometric measure is relatively simple, easily accessible, portable, and economical, and it eliminates radiation exposure to subjects in the assessment of Q-angle compared to the x-ray measure (Chevidikunnan et al., 2015; Merchant et al., 2020; Rahimi et al., 2012).

An increased or decreased Q-angle can be predisposing factors for quadriceps dysfunction, knee pain, and the occurrence of patellofemoral or tibiofemoral joint pathology, leading to early knee OA (Ekim et al., 2017; Otsuki et al., 2016; Vassão et al., 2020). The normal range of Q angle is between 10 and 14 degrees in men and 14.5 to 17 degrees in women, while its mean normal value has been reported as 13° in men and 18° in women (Wilson & Kitsell, 2002; Belchior et al., 2006). However, its values of 15° are generally considered normal (Ekim et al., 2017). The lower Q-angle values lead to increased pressure in the medial tibiofemoral compartment, while excessive Q-angles encourage the lateral force on the lateral patellofemoral as well as tibiofemoral compartments (Otsuki et al., 2016). In this context, a possible association between the presence of OA in the affected compartment and the magnitude of the Q-angle can be considered. Namely, varus alignment and medial compartment involvement are expected in patients with low Q-angle, while patients with excessive Q-angle have valgus alignment and lateral compartment involvement. However, in the present study, the Q-angles of a considerable number of patients were close to the normal value. Biomechanical and anthropometric factors, such as quadriceps muscle weakness, articular cartilage thickness, and overweight, could influence knee OA beyond the lower or excessive Q-angle (Kocak et al., 2009; Özgül et al., 2013). This could be a possible explanation of our results. Nonetheless, the malalignments in the lower extremities can be characterized by Q-angle measurement, which could have implications for diagnostic consideration and rehabilitation planning (Ekim et al., 2017). Showing a strong to excellent correlation with the radiographic method, our results verified assessing Q-angle using goniometric measure and its relation with knee disorders in the routine clinical setting.

Some methodological factors could affect the reliability of the goniometric measure of Q-angle, such as using a long-arm or short-arm goniometer in testing (Draper et al., 2011). Correctly identifications of the anatomical landmarks (ASIS, center of patella, tuberoses tibia) are important for accurately assessing the Q-angle. Long-arm goniometers allow the easy identification of these landmarks and the precise overlapping of goniometer arms with lines between the landmarks. On the other hand, a short-arm goniometer, not reaching the ASIS, may affect the accuracy of the Q-angle measure, and its accuracy mostly relies on the assessors' clinical experience and ability to correctly overlap the goniometer arms with the lines between landmarks. Correspondingly, a previous study showed higher ICCs of a long-arm goniometer (ICCs from 0.88 to 0.92) than a short-arm goniometer (ICCs from 0.56 to 0.78) (Draper et al., 2011). These suggest that the long-arm goniometer assessment is more repeatable than the short-arm goniometer assessment. The current study, using a long-arm goniometer in assessment, showed higher ICCs than those of a short-arm goniometer used in the previous study (Draper et al., 2011). Thus, our findings confirm the aforementioned suggestions. Nevertheless, the existing literature showed that the short-arm goniometric assessment of the Q-angle is still acceptable in a clinical setting, and can achieve an excellent reliability level (Draper et al., 2011).

Relative reliability is not enough to determine whether a change is clinically meaningful in a clinical setting. Therefore, absolute (SEM and MDC_{95}) reliability should be defined to interpret a minimal change in the score that is clinically meaningful for patients (de Vet et al., 2006). MDC scores are defined as the small amounts of change that are not due to measurement error. A change exceeding the MDC score represents a clinically meaningful change in the patient's score rather than a measurement error (de

Vet et al., 2006; Eymir et al., 2024). The current study assessed the relative and absolute reliabilities of the goniometric-based Q-angle measure. In the current study, low SEM and MDC_{95} values were found. This may result from the slight variations in the Q-angle degrees from patient to patient in the current study, as shown in Figure 1 (distribution plot). According to our results, the Q-angle measure using a goniometer can be performed with a small measurement error in a clinical setting. A difference greater than MDC values determined in this study can be regarded as a true difference in patients with knee OA. These values are consistent with those of previous studies conducted in different populations (Chevidikunnan et al., 2015; Rahimi et al., 2012).

The Q-angle measure is mostly used by orthopedic teams (i.e., physiotherapists and orthopedists) in pre-intervention diagnosis, treatment planning, and patients' prognosis (Örtqvist et al., 2011; Smith et al., 2008). In such a case, the inter-rater reliability of any measurement method (i.e., Q-angle measure) should be investigated among different healthcare professionals to ascertain its appropriateness if it is used among different clinicians, including physiotherapists and orthopedists. Measurement agreement was reported between a physiotherapist and an orthopedist in previous studies investigating the inter-rater reliability of different assessment methods in other populations (Springer et al., 2000; Springer et al., 2009). Nonetheless, according to our best knowledge, this is the first study that showed the inter-rater reliability of the Q-angle measure using a goniometer among physiotherapists and orthopedists in patients with knee OA. The experience of an examiner may limit the inter-rater agreement of an assessment method (Eymir et al., 2021). In our study, both examiners, physiotherapist and orthopedist, have a broad experience (> 8 years) in orthopedic assessments. This may have aided in identifying the anatomic landmarks for measuring Q-angle and thus provided excellent inter-rater reliability. On the other hand, Q-angle measurement with a goniometer is a more repeatable method as it is simple and easily applicable, requiring any sophisticated equipment (Chevidikunnan et al., 2015; Merchant et al., 2020; Rahimi et al., 2012). These may be possible reasons for the obtained results regarding inter-rater reliability in the current study.

The current study has some limitations. Firstly, the generalizability of our findings to all stages of knee OA is limited, as this study was conducted exclusively on participants with stage 3 and stage 4 knee OA. Secondly, reliability assessments were performed using an along-arm goniometer for the positions adopted during the measures in the current study; therefore, the ICCs obtained cannot be generalized to other assessment positions or imaging techniques. Further studies should be warranted to assess the reliability of other positions or imaging techniques of the Q-angle measure. Besides, in addition to lower or excessive Q-angle values, biomechanical and anthropometric variables, including quadriceps muscle weakness, articular cartilage thickness, and overweight, may lead to lower extremity malalignment and, thus, knee OA. Therefore, future studies are warranted to clarify whether these variables affect the malalignment of the lower extremities in patients with knee OA, as well.

Conclusion

According to the current findings, the Q-angle measure with a long-arm goniometer showed excellent intra- and inter-rater reliabilities in patients with knee OA and a strong to excellent correlation (concurrent validity) with radiographic assessment, a gold standard to assess Q-angle. These results support using a goniometer to assess Q-angle in patients with knee OA. Additionally, physiotherapists and orthopedists can assess interchangeably the Q-angle using a goniometer in patients with knee OA for their diagnosis, prognosis, and treatment planning. Goniometric-based Q-angle measure is a simple, easily accessible, inexpensive, noninvasive, and radiation-free alternative to radiography. These features of the goniometric-based Q-angle measure and our reliability and validity findings provide that this method may be preferred over radiographic measures to quantify changes in Q-angle in patients with knee OA in any clinical setting. Nonetheless, it should be considered that radiographic evaluation is the gold standard in assessing the Q-angle.

Authors' Contribution

Study Design: ME, NDD, BU, ME; Data Collection: ME, NDD; Statistical Analysis: ME, NDD; Manuscript Preparation: ME, NDD; Critical revision of the article: BU, ME

Ethical Approval

Ethics approval for this study was obtained from the Ethics Committee of Dokuz Eylül University (approval number: 2401-GOA). Informed consent was obtained from all participants in accordance with the Declaration of Helsinki.

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Conflict of Interest

All authors declare that they have no conflict of interest.

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ORIGINAL RESEARCH

The effects of preferred music during strength training: maximal strength, strength endurance and rating of perceived exertion

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Abstract

The purpose of this study was to examine the effects of listening to the music of choice of individuals performing strength training during training on maximal strength, strength endurance, and perceived exertion. 16 men with 1-2 years of strength training experience participated in the study. Participants' perceived exertion levels, maximum strength, and strength endurance with 75% of 1 maximum repetition were measured with the Borg scale on different days with their preferred music, non-preferred music, and no music. According to the results of the study, according to the perceived difficulty levels measured after the strength maintenance test, it is seen that preferred music ($F=6.323$; $p<0.05$) causes less effort than non-preferred music and no music. There was no difference in the rating of perceived exertion in the non-preferred music and no-music conditions. In the 1 maximal repetition bench press test, there was no statistical significance in the preferred music compared to the non-preferred music and no-music conditions ($F=0.427$; $p>0.656$). According to the results of the strength endurance test, it is seen that preferred music ($F=5.737$; $p<0.008$) provides more strength endurance than non-preferred music and no music. No difference was found between non-preferred music and no music ($p>0.05$). As a result, listening to the music that participants prefer during warm-up and exercise increases their strength endurance and decreases the perceived effort after strength endurance. It is observed that preferred or non-preferred music does not make any progress in maximal strength. Personal music preferences and listening to music with headphones during exercise sessions are recommended to improve strength and reduce perceived effort. Because music can redirect the individual's attention to thoughts unrelated to exercise at that moment. This can lead to less fatigue. At the same time, music is easily accessible, does not impose any extra cost on the person, and is seen to be effective as a psychological ergogenic aid.

Introduction

Music existed before verbal communication and has been a fundamental aspect of human culture and evolution (Mithen, 2006; Patel, 2008). Music is also considered a universal tool in terms of communication (Mehr et al., 2019). In various forms, it has influenced every society in the world, from the most primitive to the most developed. Music emphasises our daily life and accompanies a wide range of activities. It is an integral part of rituals, ceremonies and all kinds of activities. It motivates soldiers preparing to go into battle, and serves to coordinate their progress, and influences many aspects of exercise and sport (Clark et al., 2016; Levitin, 2006). Today, music has become an essential part of modern life and has also become one of the fashion trends. Therefore, listening to music during exercise has become a new sports trend (Lei & Huang, 2020). Moreover, individuals who use music during exercise believe that their mood is getting better, time passes faster during exercise, and there is an improvement in their performance. The widespread use of music in exercise environments has attracted the attention of scientists and opened the way for studies in this field. Many studies have reported that listening to music during exercise is an ergogenic aid that can increase some performance data

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(Aburto & Vargas, 2017; Eliakim et al., 2007; Hutchinson et al., 2011). However, different dimensions, such as the type of music selected, the rhythm and intensity of the music, and music preference may cause sports participants to have different physical or psychological performances (Köse, 2017). New developments in portable technology (e.g. smartphones, mp3 players) have facilitated access to music and listening to music and enabled individual selection of music during exercise (Hallet & Lamont, 2017). This has enabled athletes to exercise while listening to music of their choice. Current studies at this point have focused more on investigating how athletes improve their performance when they exercise with music of their own choice (Ballmann et al., 2021a; Greco et al., 2022; Köse, 2018). In previous years, the effect of music on sports performance, especially cardiovascular endurance and recovery, has been studied by many researchers. However, the effect of music on resistance exercises has attracted attention in recent years. Resistance exercises are generally applied by people who aim to increase muscular endurance and strength and strength performance (Folland & Williams, 2007). Optimising training regimes to maximise these aspects can lead to increased performance. Therefore, the use of ergogenic aids, substances or phenomena believed to enhance performance has become popular to improve training techniques and can range from substances such as caffeine and creatine to external influences such as music (Atan, 2013; Woolf et al., 2008). Likewise, individuals and coaches use a variety of training methods (beyond traditional resistance training) and supplements, as well as ergogenic aids such as verbal motivation or music (Filip-Stachnik et al., 2021; Pettit & Karageorghis, 2020) to improve sports performance and stamina. Music is a tool to calm fatigue-related symptoms during exercise, elicit more positive emotional responses, regulate emotional arousal and improve neural control of working muscles (Bigliassi et al., 2017; Hutchinson et al., 2018). Music has also been recognised as a sensory distraction and a means of increasing adaptation to physical activity (Clark et al., 2016). More recently, the brain mechanisms underlying the effects of music on exercise have been investigated (Bigliassi et al., 2016; Tabei et al., 2017). An increase in exercise intensity draws the focus of the exerciser's attention towards physical sensations and thus leads to a greater awareness of fatigue-related symptoms. Conversely, exposure to environmental sensory cues, such as music or video images, may direct the focus of attention during exercise to irrelevant cues outside of exercise (Karageorghis & Jones, 2014). As suggested by Conrad et al. (2007), stimulating music tracks may also regulate cardiac, respiratory and muscular activities through neurohumoral pathways. According to these researchers, music can regulate physiological arousal, leading to an effect on the activity of the autonomic system. The mechanisms highlighted by these researchers show that music may actually have a positive effect on the performance of the person by creating a psychological effect, such as other nutritional or pharmacological ergogenic aids that create physiological effects. In fact, in some of the studies, it is stated that listening to music increases recovery (Karageorghis et al., 2018; Köse, 2017; Köse & Atlı, 2019; Lim et al., 2014), increases the capacity to trigger a series of physiological changes including respiration, heart rate, motor patterns, neuroendocrine response and immunological function (Ooishi et al., 2017), running time (Köse & Atlı, 2019) and consequently improves acute exercise performance (Ballmann, 2021). As a result, listening to music helps increase athletic performance as a psychological ergogenic aid. In this context, this study aimed to investigate the effect of listening to preferred music during the training on maximal strength, strength endurance and rating of perceived exertion (RPE) of strength training individuals.

Methods

Study Design

A randomised design was used for the three conditions included in the protocol, each performed by all participants. Participants performed tests of maximal force and strength endurance under preferred music, non-preferred music, and without music conditions, and were asked to rate their self-reported RPE. Each music condition was tested on different days. Participants were allowed 3-day rest periods between each of the test days. Tests and measurements were made in the fitness center between 17:00 and 19:00 in the afternoon. To create a natural environment, measurements were made in a public fitness center that everyone uses.

Sample Size and Sampling Technique

In order to determine the number of participants in the study, power analysis was performed. According to the results of the power analysis, it was determined that 16 male participants were sufficient for the study. The mean age of the participants was 21.4 ± 2.4 years, the mean height was 175 ± 4.7 cm, and the body weight was 72.1 ± 2.4 kg. All participants were individuals who performed strength training in the gym and had 1-2 years of strength training experience. Moreover, all of the participants had been performing uninterrupted strength training at a rate of at least two training sessions per week for at least three months. Participants were advised to maintain their nutritional routines while participating in the study, but their diets were not controlled. Participants were also asked to avoid activities that would cause fatigue during the tests and measurements.The criteria for excluding participants from the study were the diagnosis of orthopaedic injury in the previous 5 months, decreased auditory perception, or any health problem that would make it impossible to perform the tests and affect the results. The ethics committee permission for the study was obtained with meeting number 2024/16 dated 23.05.2024 of the Iğdır University Scientific Research and Publication Ethics Committee.

The Intervention Programme

The data collection process for each participant was divided into four parts, three days apart. On the first day, participants signed informed consent and answered a questionnaire regarding their music genre preferences (preferred and non-preferred) while performing various daily activities during their routine (e.g., driving, leisure, and whether they listen to music while working out at the gym). The choice of music for the conditions of this research protocol was based on each participant's preferred and non-preferred music genre during training. In the music conditions, music intensity was set at 75 decibels. According to various researchers, the music volume was recommended to range between 70-82 decibels (Köse, 2020; Karageorghis et al., 1996). The music tempo was set to 137 BPM per minute (the number of beats per minute of the song) for all participants. According to previous research, music with a tempo of >120 and above BPM was stimulating (Köse, 2020; Terry & Karageorghis, 2011). The BPM of all music genres declared by the participants was standardised in the 'Virtual DJ-8' programme. Therefore, regardless of the music genre, all songs played had the same BPM rate. On each of the three days, including the warm-up period, participants performed maximal strength and strength endurance testing with their preferred type of music, with their non-preferred type of music and without music. We randomised the order of the music conditions for the three days preceding the test sessions. In the preferred and non-preferred music sessions, participants performed a routine warm-up (10 min running, 5 min stretching and a low-load movement tested) to the music of their choice. In the music-free session, no music was played either during the warm-up nor during the measurements. On the first test day, the participants performed a 1RM test in the lat-pulldown (McGuigan, 2015), followed by the bench press (Miller, 2012) in the no-music condition after warm-up. According to this determined 1RM, tests were performed in the main measurements.

Maximal Strength Measurements: Maximal strength tests were performed with Bench Press movement. According to NSCA rules, one repetition maximum (1RM) was found on the first day of the measurements. In the following days, two trials were performed in 1RM bench press measurements, and 5 minutes of rest was given between sets. During the 1RM bench press measurement, the participants lay on their backs with their heads, shoulders and hips on the bench and their legs touching the floor. The arms gripped the bar slightly wider than shoulder-width apart, and for safety purposes, a person accompanied the ascent and descent bar. For the starting position, the participants lowered the bar to the point where it touched their chest and continued to raise it until the elbows were in the full extension position. During the movement, the participant's head, shoulder and hip continued to touch the bench (Miller, 2012).

Strength endurance measurements: Strength endurance was assessed in the lat-pulldown exercise, which was chosen as it was frequently performed in resistance training and a good indicator of upper limb strength (Signorile et al., 2002). The strength continuity test was performed with a load equivalent to 75% of 1 RM determined on the first day of testing (Sheppard & Triplett, 2015). The movement rhythm was set to two seconds for the concentric movement, followed by two seconds for the eccentric movement. All participants were encouraged to perform two sets of the maximum number of repetitions until they reached muscle failure, which corresponds to the inability to sustain contractions without a change in posture or movement tempo (Steele et al., 2017). The number of lifts at the end of the two sets was recorded, and the mean value of these two sets was taken as the final strength maintenance value. Between each set, participants were allowed five minutes to rest to allow the muscles to completely recover (McGuigan, 2015).

Ratings of Perceived Exertion

We assessed participants' RPE with the Borg questionnaire (on a 10-point scale) immediately after each lat-pulldown trial. This protocol was selected as it provides a reliable, non-invasive assessment of individual effort as well as exercise intensity (Borg, 1998). We considered the mean value of the two trials as the final RPE value.

Data Analyses

For statistical analysis, the mean of the three values obtained from each test for each music condition was used. Since all variables showed homogeneity of variance and co-variance, we performed three different one-way analyses of variance (ANOVAs) using the music condition (preferred music x non-preferred music x without music) as a factor, considered repeated measures. The dependent variables were strength endurance, maximum strength and rating of perceived exertion. Post-hoc tests were performed with Bonferroni. All statistical analyses were performed using SPSS software (SPSS-22), and a significance level was taken as $p<0.05$.

Results

According to the RPE measured after the strength endurance test, preferred music ($F_{(2.28)}=6.323$; $p<0.005$; $\eta^2=0.311$) caused less exertion than non-preferred music and without music. No difference was found in the RPE in the case of non-preferred music and without music. In the one maximal repetition bench press test, it was observed that there was no statistical significance between preferred music, non-preferred music and without music ($F_{(2.28)}=0.427$; $p>0.656$; $\eta^2=0.030$). According to the results of the strength endurance test, it was seen that the preferred music ($F_{(2.28)}=5.737$; $p<0.008$; $\eta^2=0.291$) provided more strength endurance than the non-preferred music and without music. No difference was found in the case of non-preferred music and without music ($p>0.05$).

According to the RPE measured after the strength endurance test, preferred music ($F_{(2.28)}=6.323$; $p<0.005$; $\eta^2=0.311$) caused less exertion than non-preferred music and without music. No difference was found in the RPE in the case of non-preferred music and without music. In the one maximal repetition bench press test, it was observed that there was no statistical significance between preferred music, non-preferred music and without music ($F_{(2.28)}=0.427$; $p>0.656$; $\eta^2=0.030$). According to the results of the strength endurance test, it was seen that the preferred music ($F_{(2.28)}=5.737$; $p<0.008$; $\eta^2=0.291$) provided more strength endurance than the non-preferred music and without music. No difference was found in the case of non-preferred music and without music ($p>0.05$).

Table 1
The RPE, strength and strength endurance values in different music conditions (Mean ± SD).

	RPE	Maximal Strength	Strength Endurance
Preferred Music	6.20 ± 0.56*	88.13 ± 9.09	11.40 ± .73*
Non-preferred Music	6.73 ± 0.59	88.26 ± 9.11	10.93 ± .70
No Music	6.86 ± 0.64	88.26 ± 9.13	10.60 ± .83

** p < 0.05*

Discussion

In the literature, many studies have investigated the effect of different music genres and tempos on endurance performance and anaerobic performance, while fewer studies have investigated the effect of music on maximal strength and strength endurance. The current study analysed the effect of listening to preferred music genres, listening to non-preferred music genres and without music on upper limb maximal strength and upper limb strength endurance test performances, as well as perceived exertion ratings during a resistance training test. The results revealed that listening to preferred music increased participants' strength endurance more than listening to non-preferred music and the without-music condition, and participants reported lower perceived exertion after the strength endurance test. On the other hand, there was no difference in performance between the conditions of listening to a non-preferred music genre or not listening to music during the tests. In the maximal strength test, it was found that the preferred music did not increase maximal strength performance compared to the other conditions. We observed that participants perceived a lower degree of exertion when listening to a preferred music genre after strength endurance exercises, confirming previous results from other studies (Biagini et al., 2012; Nakamura et al., 2010). Silva et al. (2021) found an approximately 6% reduction in RPE when participants performed a strength test while listening to their preferred music, compared to without music and non-preferred music listening conditions. In our study, RPE was significantly reduced when participants performed a strength endurance test while listening to their preferred music genre, compared to the without music and non-preferred music listening conditions. Music appears to reduce perceived exertion and improve positive mood during exercise (Ballmann et al., 2020; Carlier & Delevoye-Turrell, 2017). Biagini et al. (2012) reported that in strength-endurance tests with and without self-selected music, they noticed a lower RPE when participants listened to music compared to without music. According to Biagini et al. (2012), even if individuals feel more tired, their subjective perception of effort tends to decrease when they hear their preferred music style. They suggest that music can reduce physiological responses in athletes while performing resistance exercises. Therefore, coaches and strength and conditioning professionals should use music to reduce RPE and physiological responses during warm-up and resistance exercises (Arazi et al., 2015). Similarly, music can be considered a legitimate ergogenic aid for well-trained athletes to reduce perceived exertion and minimise training time during the warm-up before and during resistance exercise (Arazi et al., 2015; Köse, 2019). As a result, Silva et al. (2021) stated that the decrease in RPE found while listening to the preferred music genre may be due to the ergogenic effect of music, the psychophysical effect of music on fatigue perception, or it may function as a dissociative strategy.

Strength endurance discussion: Our results show that listening to preferred music increased strength endurance more than non-preferred music and without music conditions. In literature, some studies also found that listening to the motivational music of the participants' own choice increased strength endurance by 3.9% compared to without music condition (Köse, 2018). Similarly, Bartolomei et al. (2015) reported that music increased strength endurance by 5.8%. Moreover, it was also emphasized that athletes can benefit from the option of listening to their preferred music to increase their motivation and resistance exercise performance (Ballmann et al., 2021b). It was stated that listening to self-selected music during exercise can increase lower extremity isometric strength endurance in healthy middle-aged adults. The remarkable part of this study was that the participants were older adults, unlike other studies (Greco et al., 2022). Our results were similar to previous studies (Bartolomei et al., 2015; Crust, 2004; Cutrufello et al., 2019; Moss et al., 2018; Silva et al., 2021) despite the different study designs adopted (exercise type, music direction, and sample included in the study). Especially, Crust (2004) and Bartolomei et al. (2015) revealed a greater endurance performance after listening to preferred music than in a without-music condition. Silva et al. (2021) showed that strength endurance performance increased when listening to preferred music compared to non-preferred and without music conditions. In contrast, Biagini et al. (2012) and De Lima et al. (2023) reported that preferred music did not improve bench press strength endurance performance. It was suggested that listening to preferred music during active/passive rest between sets had no effect on endurance and strength output in barbell squats and bench press performed for 3 sets at 50% of 1RM (Latocha et al., 2024). The reasons for this difference seem to be searched for in the differences between the protocols of this study and previous studies. In this study, music was only listened to during rest between sets, but not while performing the movement (Latocha et al., 2024). In most of the other studies, music was listened to during exercise or during both rest and exercise. As a matter of fact, Crust (2004) reported that listening to music during strength training provided higher muscular endurance and that listening to music throughout the entire training increased the duration of strength endurance, in contrast to listening to music before exercise. In our study, the participants started to listen to motivational music of their own choice and continued to listen to this music during exercise because listening to music before exercise helps to revitalise and motivate individuals. In studies, it has been reported that starting to listen to motivational music with warm-up before starting exercise increased strength endurance time and short-term maximal performance (Crust, 2004; Chtourou et al., 2012; Köse, 2018). Therefore, it was recommended that athletes and exercising individuals should listen to music of their own choice during the exercise session starting from warm-up to improve performance (Köse, 2019).

Maximal strength discussion: According to our results, preferred and non-preferred music had no effect on maximal strength. As a matter of fact, in a similar study, it was stated that the music listened before and during exercise did not increase maximal strength performance in bench press (Köse, 2018). Likewise, in some studies, it was emphasised that the preferred music did not affect maximal strength performance (Bartolemia et al., 2015; Greco et al., 2022). In contrast to some studies emphasising that music did not increase maximal strength, Silva et al. (2021) stated that music increased maximal strength. The reason why music did not increase maximal strength may be the lack of an effect of music on maximal strength and the lack of a rhythmic compound in a repetition at high load. Another reason predicted to reduce the effect of music on performance was the maximum intensity of the 1RM test (Bateman & Bale, 2008; Bartolomei et al., 2015; Simpson & Karageorghis, 2006). Some researchers suggest that when the workload is excessively high, an individual's attention shifts toward the painful effects of exertion, preventing them from benefiting from music during exercise due to a lack of focus on auditory stimuli (Waterhouse et al., 2010). Under conditions of maximal or near-maximal exertion, this physiological load imposed on the body induces stress, prompting the central nervous system to allocate its attentional resources entirely toward overcoming this demand to overcome the stress. As a result, it was stated that music does did not increase performance during maximum exercise because the brain cannot pay attention to the music (Köse, 2018). As a result, listening to fast or slow tempo music did not harm performance or psychological results in high-intensity resistance exercises. Personal preference may allow coaches and athletes to continue using self-chosen up-tempo music during high-intensity resistance exercises. Nevertheless, it should not be considered as an ergogenic aid to influence performance during maximal strength exercises (Svobova & Kostrna, 2024).

Conclusion

Listening to the participants' preferred music during warm-up and exercise increased their strength endurance, but decreased the perceived exertion after strength endurance. It was observed that preferred or non-preferred music did not improve maximal strength. To improve strength and reduce perceived exertion, it is recommended to listen to music with personal music preferences and headphones during exercise sessions. The reason why music can redirect the individual's attention to thoughts that are not related to the exercise at that time. This may lead to less exertion. As a result, it is seen that listening to the preferred music is effective as a psychological ergogenic aid.

Future studies should include more muscle groups and more sets. Additionally, it would be useful to investigate a lower weight performed to failure (i.e. lower % of 1-RM), as this may increase the number of repetitions and therefore the duration of the exercise. In general, it is thought that more and more comprehensive studies are needed to explore the possible benefits of music as an ergogenic aid. The effects of music on resistance exercises in different sports branches should be examined.

Authors' Contribution

Study Design: BK, AA; Data Collection: BK, AA, AK; Statistical Analysis: AA, RŞ; Manuscript Preparation: BK, AK.

Ethical Approval

The ethics committee approval for the study was obtained from the Iğdır University Scientific Research and Publication Ethics Committee with the meeting number 2024/16 dated 23.05.2024 and it was carried out in accordance with the Code of Ethics of the World Medical Association also known as a declaration of Helsinki.

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Conflict of Interest

The authors hereby declare that there was no conflict of interest in conducting this research.

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ORIGINAL RESEARCH

Analysis of YouTube content as an information source for femoroacetabular impingement rehabilitation

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Abstract

This study aims to evaluate the content, reliability, and quality of YouTube videos related to the rehabilitation of Femoroacetabular Impingement (FAI). A systematic evaluation of YouTube videos was conducted, assessing video attributes and upload sources. Two physiotherapists independently classified the videos as either useful or misleading. The comprehensiveness of the videos was analyzed using a 10-item scale, reliability was assessed with the 5-point modified DISCERN (mDISCERN) scale, and overall quality was evaluated using the Global Quality Scale (GQS). A total of 74 videos were included in the analysis, of which 26 (35.1%) were categorized as useful, while 48 (64.9%) contained misleading information. The useful videos exhibited significantly higher mean scores in comprehensiveness, reliability (mDISCERN), and overall quality (GQS) compared to misleading videos ($p < 0.05$). Furthermore, a significant difference in mDISCERN scores was observed between videos uploaded by health professionals and non-health professionals ($p = 0.042$). However, no statistically significant differences were found in comprehensiveness ($p = 0.245$) or quality ($p = 0.068$) scores. This study highlights the substantial prevalence of misleading information in YouTube videos related to FAI rehabilitation. To mitigate this issue, healthcare professionals, including physiotherapists and physicians, should actively contribute by producing accurate, evidence-based video content to ensure the dissemination of reliable and high-quality information on this topic.

Introduction

The condition known as Femoroacetabular Impingement (FAI) syndrome was initially documented in the 1990s (Ganz et al., 1991). Its structural morphology is caused by compression between the femoral head and acetabulum (Griffin et al., 2016). This phenomenon predominantly manifests in individuals aged between 20 and 45 who engage in sports and maintain an active lifestyle. The incidence of two types of FAI, Cam and Pincer, is estimated to be 37% and 67%, respectively (Frank et al., 2015). Although there are many studies on FAI syndrome, its etiology has not been fully elucidated (Grantham & Philippon, 2019).

In the treatment of FAI, surgical or conservative approaches are commonly recommended (Griffin et al., 2018). The surgical intervention is decided based on the specific impingement type (cam-pincer) exhibited by the patient, with arthroscopic procedures commonly employed for this purpose The conservative treatment approach involves implementing a supervised rehabilitation program tailored to the specific needs and functional goals of the patient. Key factors influencing rehabilitation outcomes include individual characteristics such as body composition, posture, muscle strength, and tissue adaptation to both static and dynamic conditions throughout the degenerative process. Additionally, the development of compensatory mechanisms plays a significant role in addressing these

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challenges (Anzillotti et al., 2022). Nevertheless, there is no universally accepted rehabilitation program for both conservative and post-surgical treatments (Anzillotti et al., 2022; Griffin et al., 2018).

By the conclusion of January 2024, the YouTube platform has amassed a total of over 2.7 billion accounts, with an average viewing duration of 30 minutes per visitor. Furthermore, the utilization of YouTube as a platform for accessing medical information has seen a notable uptick in recent years, gaining popularity as an effective resource (Culha et al., 2021; Güloğlu et al., 2022; Liu et al., 2019). However, due to the commercial nature of YouTube, there is a known presence of videos containing conflicting and inaccurate information alongside credible sources (Chan & Shelat, 2021; Madathil et al., 2015). The growing prevalence of YouTube has sparked interest in researching the quality and reliability of health information presented on the platform, highlighting a burgeoning need for further studies in this domain (Crutchfield et al., 2021; Culha et al., 2021; Güloğlu et al., 2022; Kocyigit & Akyol, 2021; Liu et al., 2019).

In light of the absence of a universally accepted rehabilitation protocol for FAI, coupled with the widespread utilization of YouTube as an educational tool by patients, it is imperative to evaluate the reliability and quality of video content to ensure access to accurate information. Upon reviewing the available literature, it was noted that while YouTube videos related to FAI were assessed for their quality and reliability, evaluations for FAI rehabilitation videos were lacking. This study aimed to address the lack in the literature by assessing the comprehensiveness, reliability, quality, and substance of the most popular English-language YouTube videos about FAI rehabilitation.

Methods

The current research employed a descriptive model to assess the content, comprehensiveness, usefulness, reliability, and quality of YouTube videos (www.youtube.com) related to FAI rehabilitation available on the platform. Initially, an analysis was conducted on the terminology utilized in frequently accessed video content pertaining to the subject in order to identify appropriate search terms. Based on the findings of the initial search, the terms “femoroacetabular impingement exercise”, “femoroacetabular impingement rehabilitation”, “femoroacetabular impingement physical therapy”, “femoroacetabular impingement physiotherapy”, “hip impingement exercise”, “hip impingement rehabilitation”, “hip impingement physical therapy”, and “hip impingement physiotherapy” were selected. The search was conducted on January 5, 2024, and the videos were ranked according to the number of views. When examining the behavioral patterns of internet users, it becomes evident that a significant proportion, specifically 90%, tend to predominantly focus on the content presented within the initial three pages of search engine results (Dutta et al., 2020). In this regard, solely the initial three pages (comprising 20 videos per page) pertaining to each search keyword were included for analysis. Consequently, a collective sum of 480 videos, with 60 videos corresponding to each of the eight selected keywords, were systematically reviewed.

Videos deemed irrelevant, non-English-speaking, or exhibiting substandard video quality were excluded from the analysis. In the study, videos consisting of multiple episodes were treated as a singular entity for analytical purposes. The screening methodology employed and exclusion criteria applied were in alignment with established methodologies in prior research pertaining to this subject matter (Chang & Park, 2021; Culha et al., 2021; Ertem et al., 2023). Among the videos that were excluded from the analysis, 214 were found to be duplicates, 173 were deemed irrelevant, and 19 were identified as non-English content. Following the application of exclusion criteria, the research was carried out on the remaining 74 videos, as illustrated in Figure 1. The URLs for all eligible and included videos were documented for analysis.

Evaluation of the Videos

Two experienced physiotherapists (US, SBÖ) specializing in orthopedic rehabilitation and hip pathologies independently evaluated all of the videos for features, usefulness, comprehensiveness, reliability, and quality. Any discrepancies among the authors were resolved through consensus with the involvement of the third author.

Video parameters and sources: For each video, the following parameters were recorded: (1) video duration, (2) total days posted on YouTube, (3) views, (4) likes, (5) dislikes, (6) number of subscribers, and (7) number of comments. The sources of the videos were categorized into distinct groups, such as (1) physiotherapists, (2) independent users, (3) physicians, (4) other health professionals, (5) trainers, and (6) unknown.

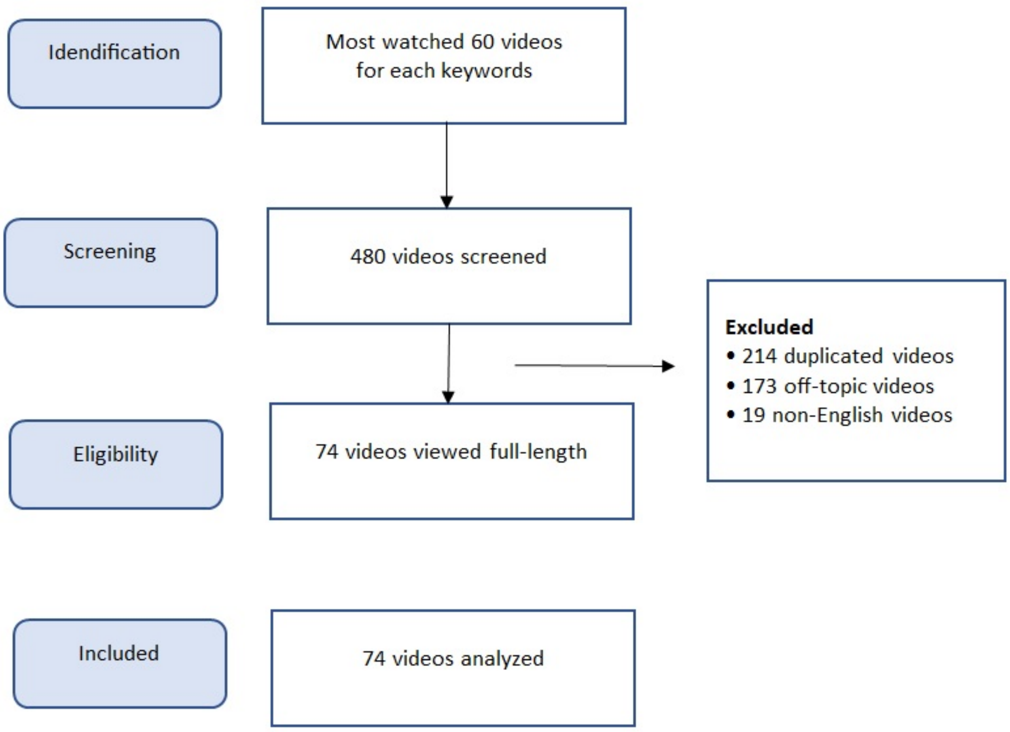

Figure 1. Flowchart of the study.

Table 1
Comprehensiveness, reliability, and quality assessment tools of YouTube videos for FAI rehabilitation.

Comprehensiveness (0.5 point per each covered in the video)
1. Explain the importance of fai rehabilitation exercises
2. Describe the timing of exercise after surgery
3. Describe posture exercises
4. Describe stretching exercises
5. Describe range of motion exercises
6. Describe strengthening exercises (core strengthening etc)
7. Describe activity modification
8. Explain the duration, frequency, technique, breath control and pain limits of exercises
9. Mention situations that necessitate the interruption of the exercise programme
10. Signify the importance of undertaking regular training
Reliability (mDISCERN)
1. Are the explanations given in the video clear and understandable?
2. Are useful reference sources given? (publication cited, from valid studies)
3. Is the information in the video balanced and neutral?
4. Are additional sources of information given from which the reviewer can benefit?
5. Does the video evaluate areas that are controversial or uncertain?
Quality (Global quality scale)
1. Poor quality, poor flow, most information missing, not helpful for patients
2. Generally poor, some information given but of limited use to patients
3. Moderate quality, some important information is adequately discussed
4. Good quality good flow, most relevant information is covered, useful for patients
5. Excellent quality and excellent flow, very useful for patients

Assessment of usefulness: The evaluated videos were classified as useful or misleading. The useful videos featured scientifically sound advice, whereas misleading videos contained inadequate or unproven information. The Kappa coefficient was employed to assess the inter-rater reliability between the two independent observers.

Assessment of comprehensiveness: To evaluate the videos' thoroughness, a 10-item assessment tool was created encompassing essential subjects related to FAI rehabilitation, as identified through literature review and expert consultation (MacLeod et al., 2015; Nepple et al., 2013). Regardless of sequence, each item was rated 0.5 points Table 1.

Assessment of reliability: The assessment of video reliability was conducted utilizing the modified DISCERN (mDISCERN) tool, originally introduced by Charnock et al. This tool consists of five questions, demonstrating a reliability score of 3 or above, suggesting a high level of reliability as per the findings presented in Table 1 (Charnock et al., 1999).

Assessment of quality: Educational quality was assessed using the Global Quality Scale (GQS) tool, comprising five criteria designed to evaluate the educational merit of online resources. The superior academic quality is associated with the higher score, wherein a maximum score of 5 signifies an excellent information flow (Bernard et al., 2007) (Table 1).

Ethics Statement

Given that the research incorporated publicly accessible YouTube videos and did not involve the use of patient data or materials, the need for institutional review board or ethics committee approval did not arise (Chang & Park, 2021; Ertem et al., 2023). All authors endorsed the study content and provided explicit consent for submission.

Data Analysis

The data was analyzed using the SPSS version 27.0 (SPSS Inc., Chicago, IL, USA). The descriptive statistics were presented as medians (minimum-maximum), counts, and percentages. The Shapiro-Wilk test was performed to assess the distribution of the data. Categorical variables were assessed through the utilization of statistical tests, including the Pearson chi-square, Fisher exact chi-square, or Fisher-Freeman-Halton tests for comparison. The Kappa value was utilized to determine the degree of agreement between two distinct observers, while the Mann-Whitney U test was employed to investigate group disparities. Statistical significance was considered at a predetermined threshold of $p < 0.05$.

Results

An analysis was conducted on the contents of 74 videos examined in the study, revealing that 26 videos (35.1%) were deemed useful while 48 videos (64.9%) were identified as containing misleading information. The interrater agreement, as quantified by Kappa scores, between two autonomous physiotherapists who conducted evaluations of the videos, was determined to be 0.94. The attributes of the videos under consideration, including their duration, time since publication, count of likes, dislikes, subscribers, and comments, are detailed in Table 2. Although a statistically significant difference was found in the duration of the videos between the categories of useful and misleading videos ($p = 0.011$), no significant differences were observed in other parameters ($p > 0.05$).

The analysis of video content revealed distinct differences in quality between videos considered useful and those found to be misleading. In particular, useful videos exhibited higher scores across various evaluation metrics compared to misleading videos. Specifically, useful videos scored a mean comprehensiveness score of 2.73 ± 0.51, mDISCERN score of 2.96 ± 1.03, and a mean GQS score of 3.57 ± 0.70. Conversely, misleading videos displayed lower scores, with a comprehensiveness score of 1.41 ± 0.48, mDISCERN score of 2.18 ± 0.98, and mean GQS score of 2.29 ± 0.84 (Table 3). Statistical analysis further confirmed the significant disparity between the two groups, as useful videos recorded notably higher scores in comprehensiveness ($p<0.001$), mDISCERN ($p<0.001$), and GQS (p:0.007) metrics compared to misleading videos. The links to the useful videos are given in Appendix A.

Table 2
Characteristics of YouTube videos.

	Useful Videos (n: 26)	Misleading Videos (n: 48)	*p*
Duration (sec.)	731.69 ± 337.15	564.70 ± 398.21	**0.011**
Total days posted on YouTube	1393.88 ± 729.87	1542.75 ± 1063.58	0.901
Number of views	286676.07 ± 552695.09	369313.81 ± 717368.23	0.675
Number of likes	7899.00 ± 16553.26	6584.31 ± 11770.29	0.599
Number of dislikes	91.42 ± 175.32	122.41 ± 250.50	0.928
Number of subscribers	1527976.92 ± 2831970.69	745532.85 ± 1116409.14	0.368
Number of comments	332.53 ± 601.35	242.83 ± 350.23	0.482

Table 3
Analysis of useful and misleading videos based on comprehensiveness, quality, reliability, and sources.

	Useful videos (n: 26)	Misleading videos (n: 48)	*p*
Comprehensiveness Score	2.73 ± 0.51	1.41 ± 0.48	**<0.001**
mDISCERN Score	2.96 ± 1.03	2.18 ± 0.98	**<0.001**
GQS score	3.57 ± 0.70	2.29 ± 0.84	**0.007**
Source of upload, *n (%)*			
Physiotherapists	17 (65.4)	14 (29.2)	**0.001**
Independent users	1 (3.8)	20 (41.7)	
Physicians	2 (7.7)	5 (10.4)	
Other health professional	1 (3.8)	6 (12.5)	
Trainer	5 (19.2)	2 (4.2)	
Unknown	-	1 (2.1)	

Table 4
Analysis of videos by source of uploads.

	Health professionals (n: 45)	Non-health professionals (n: 29)	*p*
Comprehensiveness score	1.96 ± 0.88	1.74 ± 0.63	0.245
mDISCERN score	2.68 ± 1.12	2.10 ± 0.85	**0.042**
GQS score	2.91 ± 1.04	2.48 ± 0.91	0.068
Duration (sec.)	634.53 ± 398.86	606.06 ± 365.99	0.978
Total days posted on YouTube	1297.64 ± 857.47	1789.62 ± 1039.21	0.055
Number of views	426088.55 ± 745815.38	207126.06 ± 486198.07	0.361
Number of likes	8376.06 ± 14790.50	4982.68 ± 11279.43	0.249
Number of dislikes	146.97 ± 278.33	56.51 ± 80.43	0.645
Number of subscribers	1349644.73 ± 2400049.11	509619.44 ± 354124.83	0.956
Number of comments	331.00 ± 520.07	186.44 ± 308.91	0.273

Furthermore, the analysis of the videos was based on their sources, revealing that the majority of useful videos were disseminated by physiotherapists (65.4%), whereas misleading content predominantly originated from independent users (41.7%) (Table 3). Based on the source of the videos, it was determined that there were no statistically significant variances in the mean scores for comprehensiveness, GQS means, or video characteristics. Nevertheless, statistically significant variances were noted concerning mDISCERN mean scores (p=0.042, Table 4).

Discussion

The advent of the Internet, informatics, and technology has established this platform as a primary source of health information for patients and their families. YouTube is a widely used video-sharing platform that provides users with free access. It boasts a significant user base, with over one billion individuals utilizing the platform for viewing and sharing video content (Culha et al., 2021). YouTube is often regarded as a primary resource for individuals seeking information on a variety of treatment options for different medical conditions (Ertem et al., 2023). Hence, it is imperative to thoroughly evaluate the reliability and quality of health-related videos accessible on YouTube. The present study undertook an assessment of the content, comprehensiveness, reliability, and quality pertaining to YouTube videos focusing on rehabilitation for Femoroacetabular Impingement (FAI).

The research encompasses a total of 74 videos, collectively amassing 25,180,641 views, underscoring the widespread utilization of YouTube as a primary platform for engaging in FAI rehabilitation. Upon analysis, it was ascertained that 26 of the videos provided useful information, whereas 48 videos presented misleading content. The viewership rates for the former and the latter were recorded at 29.6% and 71.4%, respectively. This distribution suggests that over two-thirds of the video content accessed by users may contain misleading information, leading to challenges in obtaining accurate and reliable information on FAI rehabilitation. The outcomes align with prior research on the efficacy of exercise videos post breast cancer surgery and self-breast examination training videos (Güloğlu et al., 2022; Rittberg et al., 2016), while deviating from the results observed in studies focusing on pelvic floor and rheumatoid arthritis exercise videos (Culha et al., 2021; Singh et al., 2012). It is postulated that such disparities may stem from variations in underlying pathologies and the sources of the videos utilized in the respective studies.

Our research findings revealed that while misleading videos garnered many views, there was a distinct preference for useful videos as indicated by higher levels of likes, dislikes, comments, and subscriber counts. Previous studies have yielded varying results; however, a consistent observation was made that useful videos tended to attract higher levels of engagement in the form of comments and likes (Chang & Park, 2021; Culha et al., 2021; Ertem et al., 2023; Güloğlu et al., 2022). Misleading videos' proliferation is believed to correlate with their higher viewership rates. Conversely, the prevalence of likes and comments on useful videos suggests that discerning viewers are capable of identifying valuable content, reflecting an escalating demand for relevant information among the audience.

The results of the video analysis indicated that the comprehensibility, reliability, and quality of the useful videos were found to be moderate. Notably, the useful videos offered more comprehensive, dependable, and superior information compared to misleading videos. These outcomes were largely in line with expectations and further corroborated by existing literature studies encompassing various disease and application videos (Culha et al., 2021; Güloğlu et al., 2022; Singh et al., 2012).

Upon analysis based on the sources of publication, it was observed that a majority of the useful videos were published by physiotherapists, contrasted with the misleading videos, which were predominantly shared by independent users. Previous research has identified a trend where educational video content containing accurate information is predominantly created by academic institutions, professional associations, medical practitioners, and physical therapists. Conversely, videos disseminating misleading information tend to originate from independent sources (Langford et al., 2021; Onder & Zengin, 2021). The phenomenon of health professionals creating useful videos aligns with existing scholarly literature and represents a predictable outcome.

Upon analysis of video sources, it was determined that videos created by health professionals, such as physiotherapists and doctors, exhibited higher levels of reliability compared to those produced by non-health professionals, such as independent users, coaches, and unknown sources. However, both categories of videos displayed similar levels of scope and quality. The creation of useful videos by coaches has been found to be impactful in achieving this outcome. Our findings are consistent with existing literatur (Culha et al., 2021), although some studies have reported divergent results (Liu et al., 2019). These variances could potentially be linked to disparities in the content covered in the videos.

Limitations

The limitations of this study include restricting the analysis to YouTube videos exclusively in English, thereby excluding content in other languages. Furthermore, the study did not utilize a standardized rating system to evaluate the reliability of potentially misleading information. Moreover, the constantly evolving dynamic structure of YouTube may lead to fluctuations over time in engagement metrics such as views, likes, and comments. In future research, engagement patterns could be investigated through longitudinal study designs, enabling a more comprehensive understanding of viewer trends.

Conclusion

The findings of this study indicate that only one-third of YouTube videos related to FAI rehabilitation offer useful information, with patients demonstrating a preference for videos containing such informative content. Notably, the most useful videos were produced by physiotherapists, exhibiting moderate levels of reliability, accuracy, and quality. These findings underscore the inadequacy of YouTube's current video regulation system in ensuring the quality of health-related content. Consequently, it is essential to implement supplementary measures to enable healthcare professionals to provide more effective guidance to patients. The first of these measures could involve the production of reliable and verified educational videos on FAI rehabilitation by academic institutions. Another important step would be to enhance the visual design and presentation of these videos, while incorporating relevant keywords and accurate tags in their titles and descriptions to improve their accessibility. In addition, actively responding to viewer comments could foster engagement and increase the overall impact of the videos. Furthermore, it is strongly recommended that the YouTube platform optimize its algorithms to prioritize high-quality health-related content and collaborate with professional healthcare institutions.

Authors' Contribution

Data curation: US, SBÖ Formal analysis: US, Investigation: US, SBÖ, EA, ZH, Methodology: US, Project administration: US, SBÖ, EA, ZH, Resources: US, SBÖ, Software: US, Supervision: US, SBÖ, Validation: US, SBÖ, Visualization: SBÖ, Writing – original draft: US, SBÖ, Writing – review & editing: US, ZH, EA.

Ethical Approval

The present study demonstrates a methodological approach that does not involve human participants or animals, thereby obviating the necessity for ethics committee approval. Instead, the evaluation was centered on publicly available videos accessible to anyone, ensuring transparency and ethical compliance within the research process.

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Conflict of Interest

The authors hereby declare that there was no conflict of interest in conducting this research.

Data Sharing Statement

Data sharing will be provided when requested from the authors.

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Appendix A. The links of useful videos.

1. https://www.youtube.com/watch?v=FVIZSNQUpIw
2. https://www.youtube.com/watch?v=bebDFSk-e70
3. https://www.youtube.com/watch?v=ATQcSDuumL8
4. https://www.youtube.com/watch?v=ulHaddxEoyE
5. https://www.youtube.com/watch?v=ueeGt9ESkNE
6. https://www.youtube.com/watch?v=SWgvSZ4KQ3w
7. https://www.youtube.com/watch?v=5vZzqMr6zlk
8. https://www.youtube.com/watch?v=BEAc-Ds7zJw
9. https://www.youtube.com/watch?v=10djgkzwsFk
10. https://www.youtube.com/watch?v=TH7QuyxXhME
11. https://www.youtube.com/watch?v=5tU8005io9w
12. https://www.youtube.com/watch?v=fT_to88kskw
13. https://www.youtube.com/watch?v=brEP7ZNowmw
14. https://www.youtube.com/watch?v=u2QF2j7TWKQ
15. https://www.youtube.com/watch?v=SLJaN1Y9xCY
16. https://www.youtube.com/watch?v=4Hhb9u4Bw_c
17. https://www.youtube.com/watch?v=MAg3lXGGaD4
18. https://www.youtube.com/watch?v=thA83oOmgsM
19. https://www.youtube.com/watch?v=S0b_I6liRLg
20. https://www.youtube.com/watch?v=jnNzUXL59F4
21. https://www.youtube.com/watch?v=y7Rq8ftOeeg
22. https://www.youtube.com/watch?v=xx6SzL-S8SY
23. https://www.youtube.com/watch?v=rrdiRWsWbVw
24. https://www.youtube.com/watch?v=pXFtN_mFuW4
25. https://www.youtube.com/watch?v=5WSvexFTbxU
26. https://www.youtube.com/watch?v=dXAG5C_TF5I

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ORIGINAL RESEARCH

Comparison of finger grip strength and manuel dexterity in vocational university students: A cross-sectional study

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Abstract

This study was planned to compare the finger dexterity, manual grip strength, and dexterity of university students studying in vocational departments, requiring manual dexterity. Participants' dominant side was determined by the Edinburgh Hand Preference Inventory, hand grip strength by hand grip dynamometer, finger strength by pinchmeter, manual dexterity by the Purdue Pegboard Test, upper extremity functionality by the upper extremity functional index, and functional disability by the Arm, Shoulder and Hand Disability Questionnaire. While there was no significant difference between the groups in finger grip and pinch grip strength in physiotherapy and rehabilitation, nursing, computer engineering and graphic design department students ($F=0.711$; $p=0.547$), a significant difference was found in tripod and lateral grip ($F=6.963$; $p<.001$; $F=3.657$; $p=0.014$). Lateral grip strength was significantly different between the Physiotherapy and Rehabilitation-Graphic Design group, the Physiotherapy and Rehabilitation-Computer Engineering group ($MD=-4.13$; $p=0.005$; $MD=-4.99$; $p<.001$, respectively). There was a significant difference between Physiotherapy and Rehabilitation, Nursing and Nursing, and Computer Engineering groups in manual grip strength ($MD=13.352$; $p<.001$; $MD=-10.487$; $p=.001$, respectively). In the Purdue Pegboard Test for manual dexterity assessment, there were significant differences between the groups in right hand dexterity, total performance, and the assembly of small items ($F=3.058$; $p=0.030$ and $F=4.272$; $p=0.006$; $F=7.099$; $p<.001$), but not in left hand and both hands performance ($F=2.476$; $p=0.063$; $F=2.661$; $p>0.05$ respectively). It was found that there was a significant difference between the groups in finger grip strength, manual grip strength and dexterity, but there was no significant difference between the groups in upper extremity functionality.

Introduction

The hand is a creative tool used for non-verbal communication. It is an important tactile organ. It performs fine and delicate tasks. Work and leisure activities require both grip strength and dexterity. Moreover, 60% of school activities involve fine motor and manual dexterity (Omar et al., 2018). Hand grip strength is important in upper extremity functional assessment (Shaheen et al., 2021). Hand grip force is a fundamental parameter in biomechanical modeling that finds many applications in the development of ergonomic tools, design of equipment and consumer products, and sports applications. Grip strength is crucial for the human body when performing the basic and delicate functions of the hand. It is also a low-cost tool to estimate the overall strength of an individual, which can reflect their general health conditions and level of physical activity. However, in many populations, it is used to ensure the health, safety, comfort, and productivity of employees and consumers, as well as for clinical purposes and to monitor recovery after injury treatment (Zaccagni et al., 2020).

Dexterity is the ability to perform a task or a group of tasks using motor functions at a certain level of efficiency or proficiency, or to execute tasks that require equipment. Dexterity primarily involves

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movement-based activities (Işik et al., 2022). Manuel dexterity is defined as the capacity to perform movements that require rapid coordination of fine and gross movements, developed through learning, training and experience. A high level of hand-eye coordination and fine motor control is required to quickly and skillfully bring both hands together to perform grasping, placing, rotating, and manipulating movements (Işik et al., 2022).

A review of studies in the literature showed that dexterity was associated with various factors, and the studies guided definition of the problem and the selection of the study's application area. Previous studies have reported quantitative assessments of manual and finger dexterity, hand anthropometry, grip strength, dominant hand, environmental temperature, gender, and the effect of working technique in many settings and situations (Işik et al., 2022; Parpucu et., 2023; Ziv et al., 2008; Lakshmanan et al., 2024).

According to Liu et al. (2017), hand mobility, stability, endurance and dexterity are maintained by coordinated intrinsic and extrinsic muscle movement. Weakness in any of these negatively affects hand grip while reducing quality of life and compromising dexterity. Furthermore, the literature has shown that training related to handgrip is necessary to improve endurance and strength as it is associated with dexterity, which improves coordination of movements and task performance (El Melhat et al., 2024).

The vocational assessment of university students regarding their majors is an emerging principle in the development of the European Higher Education Area (Kálmán et al., 2020; Kuzgun & Denat, 2020). During the learning and internship process, students do the work required by the profession. It is foreseen that hand strength and skills may change due to these processes. There is no research on how hand grip strength and skills change during training processes. It is aimed at determining the distribution of existing skills across different departments. This study was planned to compare the grip strength and manual dexterity of university students studying in hand-related vocational departments (Physiotherapy and Rehabilitation, Nursing, Computer Engineering and Graphic Design).

Methods

Design

This research is an observational comparative study. Ethical approval was obtained from Necmettin Erbakan University Health Sciences Scientific Research Ethics Committee (Decision No. 2024/883; dated December 4, 2024). Written permission was obtained from Seydişehir (Vocational School of Health Services and Vocational School, Kamil Akkanat Faculty of Health Sciences, Ahmet Cengiz Faculty of Engineering) (18.12.2024, E-79170238-100-609025). After verbal and written information about the study was given to the participants, signed informed consent was obtained from all of them (Xu et al., 2020).

Participants

Students of Necmettin Erbakan University, Vocational School of Health Services, Vocational School, Kamil Akkanat Faculty of Health Sciences, Ahmet Cengiz Faculty of Engineering, Seydişehir District, Konya Province, were included on a voluntary basis in December 2024 and January 2025 in accordance with the Declaration of Helsinki, data were collected by face-to-face interviews (Horsfall et al., 2021). Inclusion Criteria: Being a student of Physiotherapy and Rehabilitation, Nursing, Computer Engineering and Graphic Design departments, being between 18-30 years of age, being a second or third year student, not having missing fingers on both hands, not having problems with grasping and holding skills on both hands, and not having a known disease that may affect dexterity (Omar et al., 2018; Shaheen et al., 2021; Kuzgun & Denat, 2020). Exclusion Criteria: Age older than 30 years, cardiac, pulmonary and metabolic disorders affecting muscle strength, trauma, fracture, surgery and/or deformity in the upper extremity and hand, cervical radiculopathy and pain during the evaluation (Shaheen et al., 2021; Zaccagni et al., 2020; Wakelin et al., 2024).

In the calculation made with G*Power version 3.1.9.2, the effect size was 0.4, the alpha level was 0.05, and the power of the study was 0.95. It was determined that a total of 162 subjects should be included in the study, for a calculation, using the G-Power program, involving 4 groups and a single measurement. In similar studies, 180 participants were included in the study plan to account for the 10% dropout rate (Sohrabi et al., 2024). This study, a total of 182 people, including 46 in physiotherapy and rehabilitation, 46 in nursing, 45 in graphic design, and 45 in computer engineering, were included.

Outcome Measures

Physical (age, body mass index [BMI]) and sociodemographic (dominant hand, marital status, employment status) data were recorded for participants who read the informed consent form and volunteered for the study. Fat percentage, fat weight, skeletal muscle percentage, skeletal muscle weight, physical activity, and diagnosed musculoskeletal diseases were recorded using the Comedones digital smart body scale device during weight measurement. The Edinburgh Hand Preference Inventory for the dominant side was used to assess hand preference; hand grip strength was measured by hand grip dynamometer; finger strength was measured by pinchmeter; manual dexterity was assessed by Purdue Pegboard Test; upper extremity functionality was assessed by Upper Extremity Functional Index (UEFI); and functional disability was assessed by Disability Assessment of the Arm, Shoulder and Hand (DASH-T).

The Edinburgh Hand Preference Inventory is operationalized in terms of twenty daily one-handed activities to which participants must respond with their preferred hand. It consists of 10 questions, each with a 5-point Likert scale (Prichard et al., 2024).

Finger grip strength was measured with a hydraulic pinch gauge. The maximum grip strength between the first and second fingers of the dominant hand was evaluated (Berhimpong et al., 2023; Lee & Gong, 2022). During the test, a two-finger pinch test was performed in a sitting position with the elbows flexed 90°, the upper arm slightly extended and the forearm in a neutral position. In this test, the object was placed between the tip of the thumb and the tip of the index finger. The participant was asked to squeeze the instrument with as much force as possible (Mauro et al., 2025; Ziv et al., 2008). As with the hand compression force, the grip was performed three times for each test. The highest value was taken. There was a 10-second interval between one trial and the next. Pinch force assessment is a reliable tool for assessing musculoskeletal function (Szekeres et al., 2025). Test-retest reliability was high (ICC between 0.94–0.99) (Van Bergen et al., 2023).

Manual dexterity was assessed with the Purdue Pegboard Test. It measures coordinated movement or dexterity of the hands, fingers, and arms. This test consists of four parts: Parts 1 and 2 test the placement of pins using each hand separately; Part 3 tests the placement of pins simultaneously with both hands and is assessed over 30-second time periods; Part 4 is omitted or unspecified. Part 4 tested a patient's ability to make small assemblies, including pins, collars, and washers simultaneously with both hands. It was assessed over a 1-minute time frame (Işik et al., 2022; Irie et al., 2020). Test-retest reliability was established for all tests (Intraclass Correlation Coefficients, ICCs = 0.76-0.85; good) (Poo et al., 2023).

UEFI is a 20-item scale measuring upper limb activity limitation. Each item is scored on a five-point Likert scale (0 to 4; 0: extreme difficulty, 4: no difficulty). Item scores were summed to obtain the highest possible score of "80" (indicating better functional ability) and the lowest possible score of "0" (indicating worst functional ability) (Aljathlani et al., 2022).

DASH-T, developed by the American Academy of Orthopaedic Surgeons, is a scale that evaluates functional disability in the upper extremity (Arslan et al., 2023). The total score of DASH-T, consisting of 30 questions, ranges from 0, indicating no disability, to 100, indicating maximum disability. DASH-T is a reliable and valid scale used to measure all upper extremity disorders in the Turkish population (Düger et al., 2006).

Statistical Analysis

SPSS for Windows version 29.00 was used for all statistical analyses. Descriptive statistical information is given as mean and standard deviation (Mean±SD) for measured values and number (n) and percentage (%) for non-measured values. The conformity of the data to normal distribution was determined by the Kolmogorov-Smirnov test (de Jesus Correia et al., 2024; Srimani et al., 2021). Comparison of qualitative variables was conducted using chi-square analysis (Turhan, 2020). The results were analyzed with a 95% confidence interval, and we accepted $p<0.05$ as statistically significant. Hand and Finger Grip Strength Assessments and Hand Skills Tests were compared between groups. A one-way ANOVA test was used to determine differences in the means of more than two independent groups. If there was a difference between the groups; the post hoc test was used to determine the specific group(s) exhibiting the difference, using the Bonferroni correction. In addition, the p value was determined as 0.008 and the formula $(n \times (n - 1) / 2)$ was used for calculations related to this determination. The eta squared ($\eta 2$) was used as the effect size. In general, the effect size was defined as weak if the $\eta 2$ value was less than 0.01, moderate if it was 0.06, and strong if it was greater than 0.14 (Crotti et al., 2024).

Results

The physical and sociodemographic characteristics of the participants, which included 182 individuals studying in vocational departments, were similar (p>0.05). It was determined that the highest proportion of participants had the right side as the dominant side, did not engage in physical activity, did not have a diagnosed musculoskeletal disorder, was single, and did not have a job (Table 1).

Table 1
Physical and sociodemographic characteristics of university students studying in departments requiring professional skills (n=182, Mean±SD).

	Physiotherapy	Nursing	Graphic Design	Computer Engineering	Anova Test F	Anova Test *p*
Age (Year)	19.83±3.19	19.89±1.26	21.07±6.07	19.78±1.24	1.387	0.248
BMI (kg/m^2)	23.50±4.40	22.67±3.78	23.53±4.82	23.54±3.79	0.469	0.704
Fat percentage	15.35±10.57	17.21±8.62	18.59±10.25	20.55±8.40	2.421	0.068
Muscle percentage	80.28±11.07	78.79±8.05	76.27±11.62	75.25±7.87	2.510	0.060
Fat weight	11.21±10.93	12.03±7.70	14.48±11.31	15.47±8.5	1.933	0.126
Muscle weight	49.77±6.10	50.86±5.45	49.76±11.61	52.60±5.21	1.423	0.238
	(n=46) (%)	(n=46) (%)	(n=45) (%)	(n=45) (%)	x^2	*p*
Dominant hand						
Right	44 (95.65)	40 (86.96)	42 (93.36)	37 (82.23)	5.342	0.148
Left	2 (4.35)	6 (13.04)	3 (6.66)	8 (17.77)		
Physical Activity						
Doing it	5 (10.87)	7 (15.22)	14 (31.11)	11 (24.44)	6.972	0.072
It doesn't	41 (89.13)	39 (84.78)	31 (68.89)	34 (75.56)		
Diagnosed musculoskeletal disorder						
There is	1 (2.27)	1 (2.27)	2 (4.45)	2 (4.45)	0.736	0.865
None	45 (97.83)	45 (97.83)	43 (95.55)	43 (95.55)		
Marital Status						
Single	43 (97.48)	46 (100)	43 (95.55)	45 (100)	5.509	0.138
Married	3 (2.52)	0 (0)	2 (4.45)	0 (0)		
Working Status						
Not working	46 (100)	46 (100)	44 (97.78)	45 (100)	3.061	0.382
Full time	0 (0)	0 (0)	1 (2.22)	0 (0)		

Physiotherapy: Physiotherapy and Rehabilitation Department; Nursing: Nursing Department; Graphic Design: Graphic Design Department; Computer Engineering: Computer Engineering Department; BMI: Body mass index; F: One-Way ANOVA test; x²: Pearson Chi-Square test. The mean difference is significant at the 0.05 level.

Table 2
Comparison of hand grip strength and manual dexterity of university students studying in departments requiring vocational skills according to groups (n=182, Mean±SD)

Finger Grip Strength	Physiotherapy (n=46)	Nursing (n=46)	Graphic Design (n=45)	Computer Engineering (n=45)	η2	Anova Test F	Anova Test p
Pinch	10.84±4.04	10.79±3.37	11.43±3.56	11.78±4.24	0.012	0.711	0.547
Tripod	13.74±4.44	14.70±3.73	15.62±4.19	16.59±4.82	0.058	3.657	**0.014**
Lateral	14.99±5.81	16.78±5.81	19.12±5.91	19.98±5.64	0.105	6.963	**<.001**
Hand grip strength	33.28±20.90	19.93±7.54	27.55±11.26	30.42±9.55	0.125	8.475	**<.001**
Purdue Pegboard Test							
Right hand	13.04±2.14	11.96±2.14	12.58±2.30	11.87±1.97	0.049	3.058	**0.030**
Left hand	12.89±1.69	12.02±2.00	12.42±2.16	11.89±1.86	0.040	2.476	0.063
Both hands	9.49±2.01	8.46±1.69	9.03±1.74	8.94±1.54	0.043	2.661	0.050
Total	35.42±447	32.43±4.36	34.03±5.15	32.70±3.94	0.067	4.272	**0.016**
Build small assemblies	7.48±1.26	6.26±1.48	7.31±1.62	6.80±1.18	0.107	7.099	**<.001**
UEFI	73.47±7.45	69.41±13.41	70.62±6.77	70.24±11.40	0.023	1.392	0.247
DASH-T	43.50±14.31	44.26±12.56	47.31±16.98	43.16±14.07	0.013	0.763	0.516

Physiotherapy: Physiotherapy and Rehabilitation Department, Nursing: Nursing Department, Graphic Design: Graphic Design Department, Computer Engineering: Computer Engineering Department, UEFI: Upper extremity functional index, DASH-T: Disabilities of arm, shoulder, hands-T. Significant differences between groups regarding hand (p<0.05)

While there was no significant difference between the groups in finger grip strength and pinch grip strength (F=0.711; p=0.547), a significant difference was found in tripod and lateral grip (F=6.963; p<.001; F=3.657; p=0.014). This is illustrated in Table 2 and Figure 1A,B. The effect size was moderate between the groups in lateral grip ($\eta 2=0.105$). Lateral grip strength was significantly different between Physiotherapy-Graphic Design and Physiotherapy-Computer Engineering groups (MD=-4.13; p=0.005; MD=-4.99; p<.001, respectively).

There was a significant difference between the groups in hand grip strength, and the effect size was moderate (F=8.475; p<.001; $\eta 2=0.105$, Figure 1A). There was a significant difference between Physiotherapy-Nursing and Nursing-Computer Engineering groups in hand grip strength (MD=13.352; p< .001; MD=-10.487; p=.001, respectively).

In the Purdue Pedboard Test hand skills assessment, there was a significant difference between the groups in the right hand, total, and building small assemblies (F=3.058; p=0.030; F=4.272; p=0.006; F=7.099; p<.001, respectively) (Figure 2A,B,C). However, there was no significant difference in either the left hand or both hands (F=2.476; p=0.063, F values for both hands: F=2.661; p>0.05).

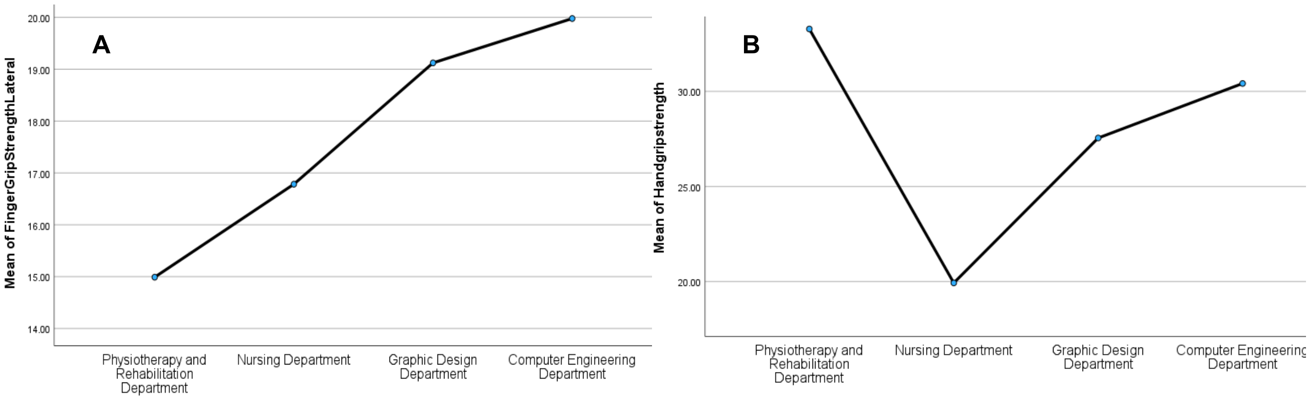

Figure 1. Finger and hand grip strength graphs between groups' means plots: **A:** Finger Grip Strength Lateral, **B:** Hand grip strength.

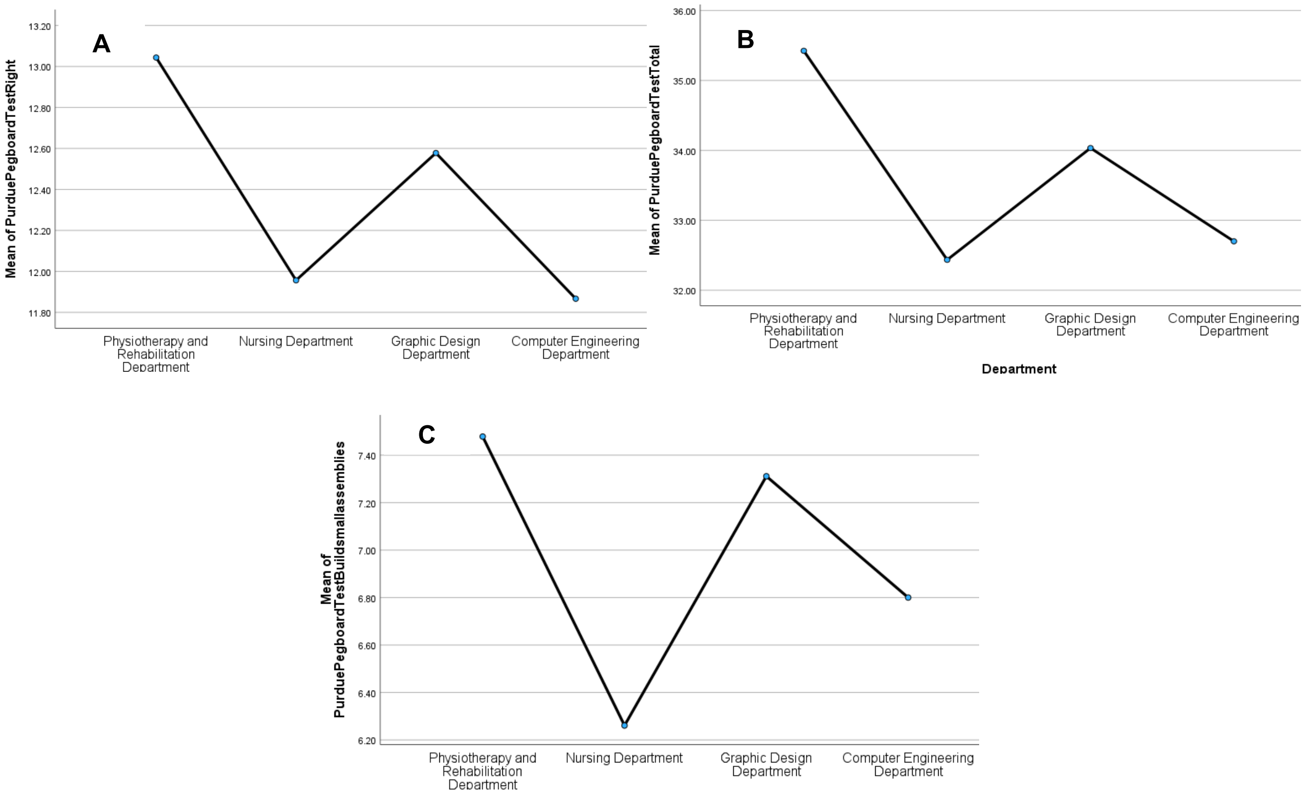

Figure 2. Purdue Pegboard test mean plots across groups: **A:** Right hand, **B:** Total, **C:** Build small assemblies.

Table 3

Comparison of hand grip strength and manual dexterity among groups of university students studying in departments requiring vocational skills using Post Hoc Test (n=182).

Finger Grip Strength Lateral	Mean Difference	Std. Error	*p*	95%Confidence Interval	
				Lover Bound	Upper Bound
Physiotherapy-Nursing	-1.79	1.21	0.837	-5.732	2.145
Physiotherapy-Graphic Design	**-4.13***	1.21	**0.005**	-8.094	-0.172
Physiotherapy-Computer Engineering	**-4.99***	1.21	**<.001**	-8.949	-1.028
Nursing- Graphic Design	-2.33	1.21	0.334	-6.300	1.620
Nursing- Computer Engineering	-3.195	1.21	0.056	-7.156	0.766
Graphic Design-Computer Engineering	-0.856	1.22	1.000	-4.838	3.127
Hand grip strength					
Physiotherapy-Nursing	**13.352***	2.79	**<.001**	4.265	22.439
Physiotherapy-Graphic Design	5.732	2.80	0.254	-3.406	14.869
Physiotherapy-Computer Engineering	2.865	2.80	1.000	-6.273	12.002
Nursing- Graphic Design	-7.621	2.80	0.043	-16.758	1.517
Nursing- Computer Engineering	**-10.487***	2.80	**0.001**	-19.625	-1.350
Graphic Design-Computer Engineering	-2.867	2.82	1.000	-12.054	6.321
Purdue pegboard test (Build small assemblies)					
Physiotherapy-Nursing	**1.217***	0.29	**<.001**	0.268	2.167
Physiotherapy-Graphic Design	0.167	0.29	1.000	-0.788	1.122
Physiotherapy-Computer Engineering	0.678	0.29	0.130	-0.276	1.633
Nursing- Graphic Design	**-1.050***	0.29	**0.003**	-2.005	-0.096
Nursing- Computer Engineering	-0.539	0.29	0.404	-1.493	0.415
Graphic Design-Computer Engineering	0.511	0.29	0.506	-0.449	1.471

Physiotherapy: Physiotherapy and Rehabilitation Department; Nursing: Nursing Department; Graphic Design: Graphic Design Department; Computer Engineering: Computer Engineering Department; UEFI: Upper extremity functional index; DASH-T: Disabilities of Arm, Shoulder, Hands-T; Significant differences between groups regarding hand (p=0.008).

In the right hand, left hand, both hands, total tests, and builds, small assemblies tests, the effect size between groups was found to be moderate (η2=0.049; η2=0.040; η2=0.043; η2=0.067, respectively). Post hoc test results, adjusted with Bonferroni correction, revealed a significant difference was found between Physiotherapy-Nursing and Nursing-Graphic Design in the evaluation of a small assembly building (MD=1.217; p<.001; MD=-1.050; p=.003, respectively) (Table 3).

There was no significant difference between the groups in upper extremity activity limitation measured by UEFI and upper extremity functional disability measured by DASH-T (F=1.392; p=0.247; F=0.763; p=0.516, respectively). The effect sizes of UEFI and DASH-T were moderate (η2=0.023; η2=0.013, respectively) (Table 2).

Discussion

It was determined that there was a significant difference between the groups in finger grip strength, hand grip strength, and hand dexterity. It was determined that the difference in finger grip strength was due to the lowest strength being in the physiotherapy and rehabilitation department, while the difference in hand grip strength and hand skills was attributed to the nursing department having the lowest average values.

In this study, there was no significant difference between the groups in terms of socio-demographic characteristics. This shows that the groups we included in the study were similar. In addition to BMI and fat and muscle ratio, the fat and muscle weight were recorded. This supports the finding that the physical characteristics of the groups in our study were similar. In similar studies regarding the subject, it was observed that physical and socio-demographic characteristics were homogeneous (Işik et al., 2022; Kuzgun & Denat, 2020; Matsuura et al., 2020).

Although there was no significant difference between the groups in pinch strength, there was a significant difference in tripod and lateral grip. It was determined that this difference in the lateral grip was due to the low grip strength of individuals in the physiotherapy and rehabilitation department. On the other hand, the middle finger grip strength of the computer department students was higher than that of students from other departments. Işık et al. (2022) found that the mean lateral grip in dental students was 20.0±5.3. Our study results were similar in lateral grip averages. Villafane et al. (2017) found that the minimal clinically important difference (MCID) values in pinch, tripod, and lateral grip were 1.56-2.21, 1.12-

2.01, 1.22-1.68, respectively. Our study results support the findings of Villafañe's study in terms of the magnitude of the difference between the groups (Villafañe et al., 2017).

In this study, it was observed that there was a difference in hand grip strength between the groups, and this difference was due to the lower muscle strength of nursing students. It is thought that the low muscle strength among nurses may result from nurses focusing on hand skills rather than muscle strength. The academic averages of the physiotherapy department students were the highest. It may be because the physiotherapy profession is focused on exercise. The mean values of hand grip strength in our study are similar to those reported by the studies of Shaheen et al. (2021), Matsuura et al. (2020), Shaheen et al., (2021) and Matsuura et al., (2020). Lakshmanan et al. (2024) found that there was a significant difference between the hand strength of physiotherapy and dentistry students. The mean hand strength of physiotherapy students was higher than that of dentistry students (Lakshmanan et al., 2024).

In this study, a significant difference was observed between the groups in the manual dexterity tests for the right hand concerning total small assembly builds, but no significant difference was found between the groups for the left hand and both hands. In the build small assemblies test, researchers determined that the difference between the groups originated from the nursing department. It is thought that this may be because the dominant side of the participants is right, enabling better exhibit their skills. Kuzgun et al. (2018) reported that, in their study on the factors affecting manual dexterity in nursing students, that the manual dexterity scores were relatively high in the 4th year of their education. Additionally, the manual dexterity scores of students who had a normal body type, had a hobby, or chose their profession voluntarily, were better (Kuzgun & Denat, 2020).

It was determined that there was no significant difference between the groups in upper extremity activity limitation and functional disability. This is thought to be, because the participants were part of the healthy population. Correia et al. found that phone addiction was associated with functionality in university students (de Jesus Correia et al., 2024). Further studies on the subject may explore the relationship between phone addiction and hand and finger strength in university students.

In this research, hand and finger strength as well as hand skills were examined in university students in this study. The findings, requiring a discussion on professional skills and differences were mentioned. Physiotherapy and rehabilitation departments are vocational departments where hand skills are important; nursing departments require fine hand skills; graphic design and computer engineering departments demand hand skills and hand strength. It is expected that test curricula and practical courses should be based on these gains. It is thought that those who gain these skills can increase their professional success.

Limitations

Our research is single-center and only students on a certain campus were included in the study. While determining the departments, hand-related vocational departments were prioritized, and departments not related to hand vocations were not included in the study. In addition, no randomization method was used in the study. Participants who expressed a desire to be part of the study after meeting with the departments were included.

Conclusions

It was determined that there was a significant difference between the groups in finger grip strength, hand grip strength, and hand skills, and there was no significant difference between the groups in upper extremity functionality. It was determined that the difference in finger grip strength was due to its being the lowest in the physiotherapy and rehabilitation department. Of the group averages, the computer engineering department had the highest performance. The difference between hand grip strength and hand dexterity test averages was due to the lowest values observed in the nursing department. The average scores for the group in hand grip strength and hand skills are the highest within the physiotherapy and rehabilitation department compared to other departments.

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Authors' Contribution

MÇ contributed to the formulation of the research design, coordination, and manuscript composition. MÇ and FT participated in conceptualizing and designing the study, data collection, data analysis, and drafting the manuscript. MÇ and FT contributed to the revision of the analytical framework and data interpretation. MÇ participated in data analysis and revising the manuscript. MÇ, FT, DS, ABT and MK contributed to the study design and data collection. All authors reviewed and approved the final version of the manuscript.

Ethical Approval

Ethical approval was obtained from Necmettin Erbakan University Health Sciences Scientific Research Ethics Committee (Decision No. 2024/883; dated December 4, 2024).

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Conflict of Interest

No potential conflict of interest was reported by the authors.

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ORIGINAL RESEARCH

The relationship between asymmetric variations in plantar pressure distribution and cardiovascular performance

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Abstract

The aim of this study is to examine the relationship between asymmetric differences in plantar pressure distribution and cardiovascular performance. The study was designed using a descriptive model. A total of 24 female athletes, with an average age of 19.08±1.6 years, participated in the study. In the study, BTS P-walk baropodometry device was used for plantar pressure measurements. In the plantar pressure analysis, maximum plantar pressure was assessed with the toes (T), metatarsal region (MR) arch region (AR) and heel region (HR) parameters, foot surface area with the forefoot (A) midfoot (B) and hindfoot (C) parameters, and rotational movements of the foot during gait with the foot progression angle parameter (FPA). Cardiovascular performance was assessed using the COSMED K5 wearable metabolic system, with VO2max as the primary parameter. The relationships between these parameters were analyzed using Pearson and Spearman correlation tests in SPSS 25 software at a significance level of $p<0.05$. The findings of the study revealed a significant negative correlation between the MR, A and FPA parameters and the VO2max parameter ($p<0.05$). The results of this study indicate that as asymmetric differences in dynamic plantar pressure distribution increase, the efficiency of oxygen utilization decreases.

Introduction

Symmetry is defined as the property of an object to exhibit complete conformity in shape, size, and form when divided along a specific axis, whereas deviation from this symmetry is referred to as bilateral asymmetry (Maloney, 2019). Asymmetric differences directly affect overall posture and movement ability by causing greater loading on the stronger side due to the principle of compensating for the weaker side (Asghari et al., 2022). Researchers emphasize that the negative effects of increased asymmetry, particularly in the lower extremities, on athletic performance and sports-related injuries should be considered not only in sedentary lifestyles but also in environments where high achievement and performance expectations are present (Heil et al., 2024).

Plantar pressure distribution is a biomechanical parameter used to evaluate the structure and alignment of the foot and its segments, as well as changes in the transmission of stress exerted on the body to the ground (Liu et al., 2024). Examined dynamically and statically on technology-supported platforms, plantar pressure distribution is considered a key determinant of balance, postural control, and gait (Patel & Balaganapathy, 2024). In asymptomatic individuals, plantar pressure is generally expected to be symmetric or slightly asymmetric. However, abnormal pressure distribution and asymmetry in plantar pressure are closely associated with foot pathologies and foot functionality (Menz & Morris, 2006; Wafai et al., 2025). Particularly in sports-related injuries, it has been identified as a risk factor, and it is recommended that preventive measures be taken against asymmetries to reduce injury risk (Fox et al., 2023).

Reports on the association of asymmetric factors with metabolic activities and cardiovascular performance appear to be conflicting (D'Hondt et al., 2024). Cardiovascular performance is an indicator that reflects endurance levels and oxygen utilization efficiency, depending on the body's oxygen transport

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capacity (Bassett & Howley, 2000). It is assessed by the maximum oxygen consumption (VO_{2max}) during exercise and is determined by the body's ability to increase blood flow to the muscles. The efficiency of cardiovascular performance is closely related to muscle strength and endurance (Coyle, 1999; Kaminsky et al., 2015). Since asymmetric differences in plantar pressure distribution may lead to greater force exertion on muscles they can increase the strain on the cardiovascular system (Grevendonk et al., 2021; Hoffman et al., 2015; Wafai et al., 2015). Therefore, evaluating the relationship between cardiovascular performance and asymmetric variations in plantar pressure distribution could be of critical importance in enhancing performance, preventing injuries, and guiding rehabilitation processes.

Considering the effects of plantar pressure distribution on the kinetic chain and body biomechanics during movement, the idea that asymmetry and imbalances in pressure distribution may be related to cardiovascular performance forms the basis of this study. Previous research has reported associations between dynamic plantar pressure distribution, athletic performance, and sports injuries in athletes (Azevedo et al., 2017; Chow et al., 2021; Mocanu et al., 2021). However, due to variations in devices and methods, there is a lack of clarity regarding reference ranges for plantar pressure distribution, particularly concerning asymmetry. Additionally, no comprehensive study has been found that specifically examines the relationship between asymmetric differences and cardiovascular performance. For these reasons, the purpose of this study is to investigate the relationship between asymmetric differences in plantar pressure distribution and cardiovascular performance.

Methods

This study was designed using a descriptive model. Ethical approval for the study was granted by Giresun University of Social, Science, and Engineering Ethics Committee (06.01.2025 - 01/01). The study was conducted in accordance with the principles of the Helsinki Declaration.

Participants

The study included 24 female athletes with an average age of 19.08 ± 1.6 years, representing various sports disciplines: football (n=6), volleyball (n=5), handball (n=4), taekwondo (n=5), and boxing (n=4). The purpose of including only female athletes in the study is to minimize gender-related variability and to enhance the reliability of the results. The sample size was determined using G*Power software (version 3.1.9.2), based on reference study results examining the relationship between plantar pressure values of the left rearfoot and balance (Anjos et al., 2010). According to a two-tailed analysis with $\alpha = 0.05$, power = 0.95, and correlation pH1 = 0.5728, the required minimum number of participants for this study was found to be 24.

Inclusion and exclusion criteria for the study: Individuals who have been licensed athletes in a sport that actively uses the lower extremity for at least the last five years, with certification each year, who have been training at least three days a week for the last year excluding the season cycles, and who have not experienced any severe foot and ankle injuries requiring intervention in the last year, were included in the study. Individuals who are in their menstrual period, those with a body mass index above the normal weight category, and those who do not meet the inclusion criteria were excluded from the study.

Table 1
Demographic information of the participants.

Variables	Mean ± SD
Age (year)	19 ± 1.66
Height (cm)	166.12 ± 5.97
Body Weight (kg)	58.83 ± 7.25
Body Mass Index (kg/m^2)	21.28 ± 2.06

Procedure

Participants meeting the inclusion criteria underwent height, weight, and body mass index (BMI) measurements before being subjected to a standardized warm-up procedure. Following the warm-up, their plantar pressure distribution and cardiovascular performance were assessed. To minimize bias and external influences on the results, all participants performed the tests barefoot. Additionally, they were instructed to refrain from engaging in any physical activity within the last 24 hours and to avoid consuming any food or beverages at least two hours prior to the measurements. The data were analysed by an independent researcher who was not involved in conducting the study. All measurements were carried out at the Performance Testing and Measurement Laboratory of the Faculty of Sport Sciences at Giresun University.

Body weight, height measurement, and body mass index (BMI) calculation

Participants' body weight was measured in kg using a scale with a precision of 0.1 kg, while their height was recorded in cm using a digital height stadiometer integrated into the same scale (SECA, Germany). BMI was calculated by dividing body weight (kg) by the square of height (m^2).

Warm-up protocol

All participants underwent a standardized 15-minutes warm-up protocol, consisting of 5 minutes of running, 5 minutes of short sprints, and 5 minutes of stretching and flexibility exercises.

Cardiovascular performance measurement

Cardiovascular performance was assessed using the participants' VO_{2max} capacities (Ozaki et al., 2010). In the measurements, the COSMED K5 (Rome, Italy) wearable metabolic system, which is recognized for its validity and reliability, and an ergospirometric treadmill (Sprintex Natural Movement treadmill, USA) were used (Zacca et al., 2023). Participants were equipped with a Hans Rudolph face mask to control gas exchange, ensuring all respiration was conducted through the mask. Before each test, the flow turbine, oxygen, and carbon dioxide analysers were calibrated according to the manufacturer's instructions for the COSMED K5 system. The metabolic system unit was secured to a comfortable harness and worn on the shoulders. The exercise protocol was synchronized with both the metabolic system and treadmill settings. VO_{2max} values were measured before and after exercise, and all data were recorded. The collected data were transmitted via Bluetooth to a laptop and analysed using COSMED software. Oxygen consumption was expressed in millilitres per kilogram per minute (ml/kg/min).

Exercise protocol

The Bruce protocol was applied to determine the participants' VO_{2max} capacities. The Bruce protocol was performed on a treadmill. The protocol has specific phases where the speed and incline increase as time progresses until the participant feels the need to terminate the test. Termination of the test by the participant indicates failure of the participant. However, participants met at least three criteria that indicated a successful test before reaching the termination point. These criteria are: VO_2 respiratory exchange ratio (RER)> 1.10, a plateau in VO_{2max}, and 95% of age-estimated maximum heart rate (HR) (HRmax = 220- age) (von Schaumburg et al., 2022).

Dynamic plantar pressure measurement

Dynamic plantar pressure was assessed using the P-Walk baropodometry system (BTS, S.p.A., Italy), which has a 2.4-meter-long platform. Before the evaluation, the device was calibrated individually for each participant. Prior to the test, participants were instructed to walk on the system for 2 minutes to familiarize themselves with the platform. However, they were not informed about the exact start time of the test. The test was initiated at the first minute of walking while the participant was still outside the platform. Once the participant completed their walk and exited the platform, the system automatically ended the test. In the plantar pressure analysis, maximum plantar pressure (kPa) (Figure 2) was assessed with the toes (T), metatarsal region (MR) arch region (AR) and heel region (HR) parameters, foot surface area (%) (Figure 2) with the forefoot (A) midfoot (B) and hindfoot (C) parameters, and rotational movements of the foot during gait with the foot progression angle (°) (Figure 3) parameter (FPA) (McNab et al., 2022).

Figure 1. VO_{2max} and plantar pressure measurement.

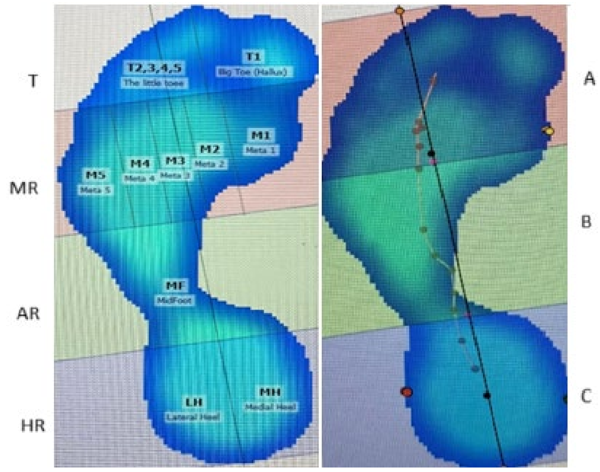

Figure 2. Maximum plantar pressure (T, MR, AR, HR) and foot surface area (A, B, C) parameters.

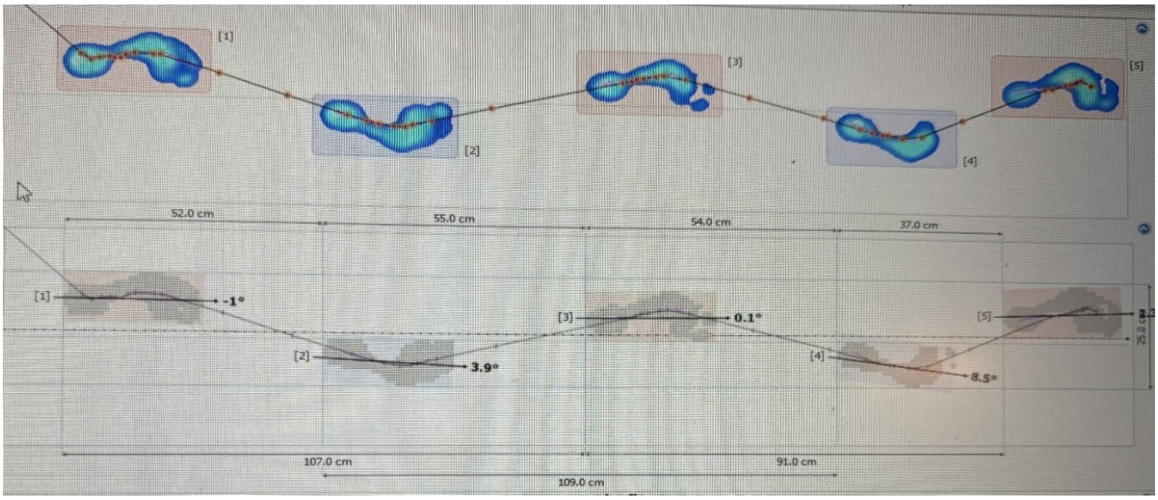

Figure 3. Foot progression angle (FPA) parameter.

Data Analyses

To determine asymmetry in plantar pressure distribution, the differences in pressure distribution between the right and left feet were calculated, and absolute values were considered in the analysis. Data analysis was performed using SPSS 25.0 software. Initially, the Shapiro-Wilk normality test was applied to assess the distribution of the data: 1) for parameters that showed normal distribution (VO_{2max} and FPA), relationships were analysed using the Pearson correlation test, 2) for parameters that did not follow normal distribution (T, MR, AR, HR, A, B and C), relationships were evaluated using the Spearman correlation test. Results were analysed at a significance level of $p<0.05$. The correlation coefficients were interpreted as follows: 0.00-0.25 little or no correlation, 0.26-0.49 low correlation, 0.50-0.69 moderate correlation, 0.70-0.89: high correlation, and 0.90-1.00: very high correlation (Carter & Lubinsky, 2016).

Results

The results of the normality analysis of the variables are presented in Table 2, and the asymmetric differences in the distribution of measured plantar pressure and VO_{2max} are presented in Table 3.

Table 2
Shapiro-Wilk normality test results.

Variables	*p*-values
VO_{2max}	0.135
T (kPa)	0.001*
MR (kPa)	0.002*
AR (kPa)	0.048*
HR (kPa)	0.000*
A (%)	0.000*
B (%)	0.000*
C (%)	0.000*
FPA (°)	0.058

*VO_{2max}: Maximum oxygen consumption capacity, T: Toes, MR: Metatarsal region, AR: Arch region, HR: Heel region, A: Forefoot, B: Midfoot, C: Hindfoot, FPA: Foot progression angle, *Statistical significance at p<0.05.*

Table 3
Descriptive statistics of VO_{2max} and plantar pressure asymmetry.

Variables	Mean ± SD
VO_{2max}	50.42 ± 4.66
T (kPa)	80.45 ± 91.36
MR (kPa)	27.70 ± 27.48
AR (kPa)	16.54 ± 13.92
HR (kPa)	14.83 ± 18.09
FPA (°)	4.03 ± 3.00
A (%)	2.83 ± 3.62
B (%)	4.37 ± 5.28
C (%)	2.53 ± 3.29

VO_{2max}: Maximum oxygen consumption capacity; T: Toes, MR: Metatarsal region; AR: Arch region; HR: Heel region; A: Forefoot; B: Midfoot; C: Hindfoot; FPA: Foot progression angle.

When examining the relationship between asymmetry in plantar pressure distribution and VO_{2max}, a significant negative correlation was found between VO_{2max} and the MR, A and FPA parameters ($p<0.05$). However, no significant differences were observed for the other parameters ($p>0.05$; Table 4).

Table 4
The relationship between plantar pressure distribution asymmetry and VO_{2max}.

Variables		VO_{2max}
T (kPa)	r/rho	-0.351
	p	0.093
MR (kPa)	r/rho	-0.467*
	p	0.021
AR (kPa)	r/rho	-0.300
	p	0.154
HR (kPa)	r/rho	-0.321
	p	0.126
A (%)	r/rho	-0.522**
	p	0.009
B (%)	r/rho	-0.386
	p	0.063
C (%)	r/rho	-0.084
	p	0.696
FPA (°)	r/rho	-0.466*
	p	0.022

*VO_{2max}: Maximum oxygen consumption capacity, T: Toes, MR: Metatarsal region, AR: Arch region, HR: Heel region, A: Forefoot, B: Midfoot, C: Hindfoot, FPA: Foot progression angle, * p<0.05, ** p<0.01.*

Discussion

In this study, the relationship between asymmetric differences in plantar pressure distribution and cardiovascular performance was examined. In previous studies, no comprehensive research has been found on the relationship between bilateral asymmetry in plantar pressure distribution and cardiovascular performance elements. From this perspective, the limitation in the literature reveals the originality of the present study. The results of the study showed a significant negative relationship between the plantar pressure parameters MR, A, and FPA and VO_{2max} consumption.

It is emphasized that VO_{2max} consumption is an important parameter in evaluating cardiovascular performance (Bassett & Howley, 2000; Day et al., 2003). The metabolic system used in the study provides valid and reliable results regarding VO_{2max} consumption (Bassett & Howley, 2000). The increase in VO_{2max} consumption is interpreted as being directly proportional to the improvement in cardiovascular performance (Wang & Zhou, 2021). The primary finding of the study is that as the maximum pressure distribution in the forefoot and the asymmetries in the forefoot surface area increase, VO_{2max} consumption decreases (Table 4). The foot is the final region of the movement chain, where all the stress applied to the body in both static and dynamic conditions is transferred to the ground (Liu et al., 2024). Therefore, the proper absorption and transmission of the encountered load to the ground are directly influenced by the anatomical structure of the foot and the coordinated movement of its segments (Sivachandiran & Kumar, 2016). From this perspective, these findings align with reports emphasizing that the morphological and kinesiological analysis of the foot and its segments can be among the determinants of athletic performance (Chow et al., 2021; Mocanu et al., 2021).

Although the results of the study provide supporting insights into the importance of plantar pressure distribution in athletic performance, the research hypothesis is based on asymmetry in plantar pressure distribution. Asymmetry in plantar pressure distribution refers to the pressure differences between the right and left foot (Gawronska & Lorkowski, 2021). Previous reports indicate a consensus among researchers that asymmetrical structures disrupt movement patterns and, consequently, optimal biomechanical efficiency (Hart et al., 2014; Kanchan et al., 2008). It has been emphasized that impairments in biomechanical efficiency are directly linked to cardiovascular performance and aerobic endurance (Fox et al., 2023; Bishop et al., 2022). Studies have shown that individuals with lower extremity asymmetry exert greater vertical forces on their knee joints during physical activity (Melo et al., 2020; Thijs et al., 2007). This may lead to changes in muscle properties such as muscle tone, stiffness, and elasticity, leading to the development of stiffer tendon structures in the knee extensors (Kubo et al., 2000). Increased tendon stiffness has been reported to induce an exaggerated joint muscle-tendon stretch reflex, ultimately resulting in higher energy demands (Beck et al., 2018; Jin & Hahn, 2018). It has been reported that asymmetric differences increase the demand on soft tissues, and this increased demand disrupts oxygen consumption efficiency, leading to an increased cardiac load and higher energy expenditure (Salvador et al., 2016). The results of this study suggest that the relationship between plantar pressure distribution asymmetry and VO_2 consumption may be due to the biomechanical changes caused by asymmetric differences during movement. These changes require the body to increase muscle activation to maintain balance, which in turn reduces the efficiency of energy and oxygen utilization.

The findings of the current study highlight asymmetry in the forefoot. Previous studies examining plantar pressure distribution have primarily focused on balance, postural control, and sports injuries (Azevedo et al., 2017; Chow et al., 2021; Mocanu et al., 2021; Wafai et al., 2015). Cobb et al., (2004) reported that increased forefoot varus could negatively impact postural stability, while Sarıalioğlu (2023) emphasized a positive relationship between a wider forefoot and balance performance. Additionally, a study by Bito et al. (2018) reported that asymmetry in the transverse arch is associated with foot injuries. Prior research indicates that forefoot morphology and forefoot pressure distribution influence balance functions. It is emphasized that maintaining and sustaining balance is associated with cardiovascular performance and that the effort to preserve impaired balance reduces the efficiency of oxygen utilization (Guner & Alsancak, 2023; Yalfani & Asgarpoor, 2024). The findings in the literature appear to support the results of the present study.

The second key finding of the study is that as FPA asymmetry increases, there is a significant relationship indicating a decrease in VO_{2max} consumption (Table 4). FPA represents the angle between the long axis of the foot and the walking direction, influenced by rotational movements of the foot during gait. An increase in FPA asymmetry signifies a growing angular difference between the right and left foot in gait kinetics, highlighting asymmetrical FPA as a gait disorder (Di Stasi et al., 2013; Rerucha et al., 2017). FPA significantly impacts walking and running biomechanics, as well as plantar pressure distribution (Lai et al., 2014; Nishizawa et al., 2022). Previous research has indicated that excessive rotation in FPA increases pressure on the soft tissues of the foot, knee, and hip, compromising lower extremity functionality (Buldt et al., 2018; Iijima et al., 2019). The functionality and coordination of body components are recognized as key factors in successfully performing required movements. The effort to eliminate the mismatch caused by asymmetry is known to lead to higher energy costs and inefficient oxygen utilization, accelerating the onset of fatigue (Konieczny et al., 2023). Additionally, reports indicate that asymmetry in FPA can cause balance issues, increasing the frequency of sports injuries (Bito et al., 2018; Guan et al., 2022). When the findings of the present study are evaluated in light of this information, the negative relationship between FPA and VO_{2max} can be attributed to the changes and disruptions in body kinematics caused by FPA asymmetry. The extra effort required to compensate for impaired kinematics may reduce the efficiency of oxygen consumption.

Limitations

The first limitation of this study is the sample size. Although power analysis indicated that a minimum of 24 participants was sufficient, larger groups could enhance reliability and contribute to the generalizability of the findings. The second limitation is the lack of repeated measurements, particularly in the assessment of cardiovascular performance. While plantar pressure distribution is a biomechanical characteristic, it is also influenced to some extent by anthropometric structure, meaning that similar results may be obtained in measurements conducted at different times. However, cardiovascular performance assessments are subject to a much greater range of internal and external factors, which may lead to significant variability in the results.

Conclusion

The results of this study indicate that as asymmetric differences in dynamic plantar pressure distribution increase, the efficiency of oxygen utilization decreases. While these findings are promising for future research in this field, the study's limitations highlight the need for more advanced investigations to draw definitive conclusions.

Practical Applications

While acknowledging the limitations of the study, several practical application suggestions can be made based on the research findings. According to these results;

- The early detection of individual asymmetries through plantar pressure analysis may be important for identifying personalized intervention strategies aimed at maintaining or improving VO_{2max} levels.
- These findings may suggest that plantar load balance should be considered an important target parameter in aerobic endurance development protocols.
- Training programs aimed at optimizing bilateral load distribution may contribute to the improvement of cardiovascular capacity.

Authors' Contribution

The research is single authored

Ethical Approval

The study was approved by the Giresun University of Social, Science, and Engineering Ethical Committee (dated 06.01.2025 and numbered 01/01) and it was carried out in accordance with the Code of Ethics of the World Medical Association also known as a declaration of Helsinki.

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Conflict of Interest

The authors hereby declare that there was no conflict of interest in conducting this research.

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ORIGINAL RESEARCH

Investigation of the relationship between core muscle endurance and postural habits and awareness in young adults

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Abstract

The study investigated the relationship between core muscle endurance, postural habit, and awareness in young adults. Healthy individuals between the ages of 18 and 25 with no back or neck disorders were included in the study. Postural habits and understanding of the participants were assessed using the Postural Habits and Awareness Scale (PHAS), and core muscle endurance was measured using the Mcgill Core Endurance Tests. As a result of the study, a significant positive correlation was found between postural habit score and trunk flexor test time ($r = 0.324$; $p = 0.047$), trunk extensor test time ($r = 0.529$; $p = 0.001$), side bridge test time ($r = 0.337$; $p = 0.039$) and plank test time ($r = 0.508$; $p = 0.001$). However, no significant relationship was found between postural awareness score and core muscle endurance ($p > 0.05$). The study findings reveal that core muscle endurance is related to postural habits but is not directly related to postural awareness. As a result, it was emphasized that core muscle endurance is an essential factor in developing and maintaining postural habits. These findings indicate that improving postural habits may be essential to support musculoskeletal health.

Introduction

Posture refers to the position of the human body in space and the alignment of body segments relative to each other (Elliott et al., 2005). While the alignment that places minimum stress on the joints is defined as good posture, misalignment of body segments and the resulting increase in stress on the joints is considered bad posture (Yamak et al., 2018; Yasmeen et al., 2014). The ability of an individual to consciously perceive the difference between good and bad posture is called postural awareness.

Postural awareness enables the conscious awareness of body posture through proprioceptive feedback transmitted to the central nervous system (Cramer et al., 2018). To maintain healthy posture habits in daily life, it is of great importance for the individual to be aware of posture changes. Poor posture habits can change muscle tone and alignment, leading to poor posture patterns and overall body asymmetry (Bayar et al., 2023). Postural habits are the body positions that individuals acquire and constantly apply in their daily lives, and these habits play an important role in maintaining posture over time. Long-term poor posture habits can increase the load on the spine, leading to pain and other musculoskeletal problems. Therefore, postural habits are fundamental to maintaining a healthy body posture (Bayar et al., 2023; de Assis et al., 2021).

The most important muscle group in maintaining posture is the core muscles. The core muscles consist of superficial and deep muscles that stabilize the spine and support trunk movements (Hodges & Richardson, 1997). Among these muscles, the transversus abdominis, multifidus, diaphragm, and pelvic floor muscles play a critical role (Bergmark, 1989). Sufficient endurance in the core muscles is important in providing spinal stability, increasing sports performance, preventing injuries, and being effective in rehabilitation processes (Khaiyat & Norris, 2018; Maffulli et al., 2016; Tong et al., 2014).

Weakening of the core muscles can lead to low back pain and negatively affect postural control (Akuthota & Nadler, 2004). In addition, fatigue of the

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core muscles during prolonged sitting or standing affects postural adaptations and causes posture disorders (Granacher et al., 2013). These posture disorders can also negatively affect postural habits because poor posture habits disrupt the balance in the spine and overload the muscles, further increasing muscle fatigue.

Although many conditions associated with weakness of the core muscles have been described in the current literature, studies examining the relationship between core muscles and postural awareness and habits in young adults are limited. Low core muscle endurance can make it challenging to maintain postural stability during prolonged sitting, standing, or repetitive movements. This can lead to disruption of postural habits and the emergence of posture-related musculoskeletal problems in the long term (Marshall & Murphy, 2005). In particular, weak core muscles can negatively affect postural awareness, causing an individual to be unable to perceive changes in body posture adequately and to develop compensatory mechanisms. Such mechanisms can lead to poor postural habits and disruption of spinal alignment over time. Therefore, this study examined the relationship between core muscle endurance, strength, postural awareness, and habits.

Methods

Participants

University students aged 18-25 who agreed to participate were included in the study. Approval was obtained from the ethics committee of Erzurum Technical University Scientific Research and Publication Ethics Committee for the conduct of the study, and ethical rules were followed in all procedures (Meeting Number: 01, Decision Number: 11, Date: 02.01.2025). Written consent was obtained from all participants before starting the study.

The minimum number of individuals required for the study was calculated using the G*Power program. It was planned that the study should be completed with 34 participants at a 95% confidence interval, 0.05 level of significance, 0.5 effect size (obtained from reference study data(Paramanidis et al., 2023)), and 0.90 power. The study was completed with 40 participants.

Sedentary healthy individuals between the ages of 18 and 25 who did not have any back or neck problems were included in the study. Individuals with any neurological, orthopedic, or cardiovascular issues or a history of surgical intervention or traumatic injury to the spine or upper extremity within the last year were excluded from the study. Individuals who regularly exercised were also excluded from the study.

Procedure

Postural habits and awareness

To determine the level of postural habits and awareness of the participants, the 19-item Postural Habits and Awareness Scale (PHAS), which was developed by Bayar et al. for Turkish validity and reliability, was applied. PHAS is a scale designed to evaluate awareness of body position and postural habits. This scale helps to determine how well people have correct posture habits in their daily lives and how much awareness they have about their posture. The highest score for postural habits is 35, and the highest for postural awareness is 60. The total score range of the scale is 0-95 points, and a high score indicates good posture and awareness (Bayar et al., 2023).

Core muscle endurance

The participants' core muscle endurance was evaluated using the time spent in the plank position. For the plank, the abdominal, leg, and chest muscles were used, and a position was taken at 45 degrees to the ground. The shoulders were kept back; the chest was up; the whole body was squeezed with the help of the fingertips on the elbows, and the person was asked to look ahead. The evaluator recorded the time using a digital stopwatch (Reiman & Manske, 2009) (Figure 1).

Core muscle endurance was also assessed using three core endurance tests developed by McGill. The McGill Core Endurance Tests are the trunk flexor, trunk extensor, and side bridge tests. The trunk flexor test was performed with the trunk at 60° flexion and knees and hips at 90° flexion. Arms were crossed on the chest, and individuals were asked to maintain this position for as long as possible. The trunk extensor test was performed in a prone position on the treatment table. The pelvis, hips, and knees were fixed to the treatment table up to the level of the anterior superior iliac spine. Individuals were asked to maintain a horizontal body position with arms crossed on the chest for as long as possible. A side bridge test was performed on the mat while lying on the side. While lifting the hips upwards on the mat, the body weight was supported only by the lower elbows and feet. Tests were terminated when the positions were disrupted. Measurement results were recorded in seconds (Waldhelm & Li, 2012) (Figure 2).

Figure 1. Plank test.

Figure 2. McGill core endurance tests.

Data Analyses

For data analysis, the Windows SPSS package program was used (IBM SPSS Statistics 25.0, IBM, New York, USA). The Shapiro-Wilk test was used to check the normal distribution assumption and to examine whether the data were normally distributed. Mean, standard deviation, median, and interquartile range were used to distribute the participants' demographic data and test results. The Spearman correlation test was used to evaluate the ordinal relationship between variables. For all analyses, $p<0.05$ was considered statistically significant.

Results

A total of 40 participants were included in the study. The mean age of the participants was 21 ± 1.04 years. 55% of the participants were female, and only 4% were smokers. Demographic data of the participants are given in Table 1. The participants' PHAS scores and data obtained from core muscle endurance tests are summarized in Table 2.

According to the results of Spearman correlation analysis, trunk flexor test duration showed a significant positive correlation with postural habit score ($r = 0.324$; $p = 0.047$). Trunk extensor test duration also significantly correlated with postural habit score ($r = 0.529$; $p = 0.001$). Side bridge test ($r = 0.337$; $p = 0.039$) and plank test ($r = 0.508$; $p = 0.001$) also significantly correlated with postural habit score. However, no significant correlation was found between postural awareness score and any core muscle endurance test ($p > 0.05$; Table 3).

Table 1

Demographic characteristics of participants (n=40).

Variables	Median (IQR)
Age (years)	21 (20-22)
Weight (kg)	63 (52.75-76.5)
Height (cm)	164(159.25-165.75)
BMI (kg/m^2)	21.7 (19.8-25.2)
	n (%)
Smokers	4 (10)
Gender	
Female	22 (55)
Male	18 (45)

IQR: Interquartile range.

Table 2

PHAS scores and core muscle endurance test results.

Variables	Mean ± SD
Trunk Flexor test (sec)	44.06 ± 14.01
Trunk Extensor test (sec)	45.79 ± 27.79
	Median (IQR)
Side bridge test (sec)	24.06 (17.75-35.30)
Plank test (sec)	54 (43-77.75)
PHAS- Postural Habit score	21 (17.75–24.50)
PHAS- Postural Awareness score	41 (38.50-43)
PHAS Total	63 (58.75-66.50)

PHAS: Postural Habits and Awareness Scale; IQR: Interquartile range; SD: Standard Deviation.

Table 3
Relationship between PHAS scores and core muscle endurance tests.

Variables		PHAS Postural Habit score	PHAS Postural Awareness score	PHAS Total
Trunk Flexor test (sec)	r	0.324	0.263	0.464
	p	**0.047**	0.111	**0.003**
Trunk Extensor test (sec)	r	0.529	0.20	0.501
	p	**0.001**	0.905	**0.001**
Side bridge test (sec)	r	0.337	0.050	0.276
	p	**0.039**	0.765	0.094
Plank test (sec)	r	0.508	0.253	**0.395**
	p	**0.001**	0.126	**0.014**

PHAS: Postural Habits and Awareness Scale.

Discussion

This study's findings indicate a significant relationship between core muscle endurance and postural habit in young adults. Still, it is not directly related to postural awareness.

Core muscles maintain spinal stability, support force production in the upper and lower extremities, and control body movements (Akduman et al., 2019). Core muscle endurance is one of the main factors determining the core muscles' ability to maintain posture and movement. The literature has stated that core muscle endurance is associated with better posture and that the risk of postural disorders is reduced in individuals with adequate core muscle endurance. For example, a study conducted on farmers found a strong correlation between core muscle endurance and low back pain, emphasizing the importance of core endurance in maintaining proper posture during physically demanding tasks (Anggreni et al., 2024). Similarly, methods recommended for correcting posture disorders include strengthening core muscles and endurance exercises (Bansal et al., 2014). Studies on athletes have shown that core training, especially on moving surfaces, improves posture stability by increasing core muscle endurance (Nuhmani, 2021). A study on basketball players also reported a positive correlation between core muscle endurance and postural stability (Cengizhan et al., 2019).

Although the relationship between core muscle endurance and posture has been widely studied in the existing literature, its relationship with postural habits and awareness has not been sufficiently investigated. Core muscle endurance can affect not only posture but also postural habits and awareness. Tsao and Hodges reported that postural awareness training improved muscle activation and postural control (Tsao & Hodges, 2008). Additionally, Hodges and Richardson proposed that motor strategies shape postural control mechanisms learned over time (Hodges & Richardson, 1999). These findings suggest that core muscle endurance may also affect postural habits that an individual develops unconsciously. In the current study, core muscle endurance was related to postural habits. This suggests that core muscle endurance provides instant postural stability and may also affect the postural habits that an individual adopts in the long term. However, this study found no significant relationship between postural awareness and core muscle endurance. This result suggests that postural awareness may be affected more by cognitive processes, education level, habits, or ergonomic factors.

Postural habits and awareness are critical factors affecting physical health, especially in adolescents and young adults. Research shows that poor postural habits, often exacerbated by sedentary lifestyles and excessive internet use, can lead to musculoskeletal problems such as back pain (Çankaya et al., 2024; Schwertner et al., 2022). Awareness of and correcting these habits is crucial to preventing musculoskeletal disorders (Schwertner et al., 2022). Therefore, this study evaluated postural awareness and habits in young adults, and a multi-faceted examination of core endurance was provided. In addition, the high applicability of the tests used in the study and the fact that they were performed under field conditions increase the practical value of the study.

The practical value of our study lies in the use of applicable and easily accessible tests for the assessment of postural habits and awareness in young adults. In particular, the fact that the tests used to assess core muscle endurance can be easily applied under field conditions increases the practicality of the study in terms of clinical and sports sciences.

This study has some limitations. First, factors affecting postural habits, such as the participant's physical activity level and daily living habits, were not evaluated in detail. Examining these factors may provide more comprehensive information about the formation process of postural habits. Second, analyzing only the endurance dimension of core muscle functions may have limited the full extent of muscle functions. Future studies can examine this relationship more comprehensively with objective muscle strength assessment methods such as isokinetic strength measurements.

In addition, the study's cross-sectional design prevents the determination of causal relationships between core muscle endurance and postural habits. In the future, longitudinal studies can examine the effects of changes in core muscle endurance on postural habits over time.

Conclusion

As a result, a significant relationship between core muscle endurance and postural habits in young adults was found in the study. Still, no direct relationship was found between postural awareness and core muscle endurance. The findings suggest that core muscle endurance may affect postural habits, but postural awareness is more affected by cognitive processes, education level, and environmental factors.

Authors' Contribution

Study Design: AY; Data Collection: AY, RY; Statistical Analysis: RY; Manuscript Preparation: AY, RY.

Ethical Approval

The study was approved by the Erzurum Technical University Scientific Research and Publication Ethics Committee (Meeting Number: 01, Decision Number: 11, Date: 02.01.2025) and it was carried out in accordance with the Code of Ethics of the World Medical Association also known as a declaration of Helsinki.

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Conflict of interest

The authors hereby declare that there was no conflict of interest in conducting this study.

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