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Original article

Validity and Reliability of an Adapted Leg/Back Isometric Strength Testing Device

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Abstract

The leg/back dynamometer (LBD) is a valid lower-body strength test. For people stronger than the typical device, a crane scale could provide an adapted leg/back dynamometer (ALBD), although validity and reliability analyses are needed. Fifty participants completed three testing sessions, consisting of three LBD and ALBD trials each. One-sample t-tests determined whether LBD and ALBD mean differences were significant compared to 0. Paired samples t-tests and effect sizes (*d*) compared average and maximum LBD and ALBD. Pearson's correlations and regression derived LBD and ALBD relationships. Intra-class correlation coefficients (ICC) and coefficient of variation (CV) assessed reliability. A three-way repeated measures ANOVA compared between-session LBD and ALBD. Test usefulness was analyzed by typical error (TE) and smallest worthwhile change (SWC). The mean differences analyses indicated a fixed bias ($p \leq 0.04$); the LBD recorded greater values than the ALBD ($p < 0.01$; $d = 0.43$-0.89). Relationships between the LBD and ALBD across all sessions were significant ($p < 0.001$; $r = 0.902$-0.985), with 94% explained variance. The ICCs and CVs for all sessions were acceptable (ICC≥0.97; CV≤6%). There were no significant LBD or ALBD differences between Sessions 1 or 2. However, average and maximum LBD for Session 3 was greater than Sessions 1 and 2; Session 3 average ALBD was greater than Sessions 1 and 2 ($p \leq 0.002$); and maximum ALBD was greater than Session 1 ($p \leq 0.042$). The LBD and ALBD were useful (TE=5.13-5.65kg; SWC=7.26-7.99kg). The ALBD can measure strength, although the data was lower than the LBD. The LBD and ALBD are reliable and useful; two practice sessions could enhance reliability.

Keywords: Cane scale, Familiarization, Intra-class correlation coefficient, Lower-body strength, Leg/back dynamometer

Introduction

Strength is an essential quality for many different athletic (Suchomel et al., 2016) and occupational (Orr et al., 2022) activities. As a result, strength testing is a common tool used by practitioners. The data derived from strength tests can highlight the limitations for a particular individual and help drive appropriate training programs (McGuigan, 2015). Repetition-maximum (RM) tests with dynamic exercises (e.g., bench press, squat, deadlift) are often used to measure strength. While valuable, this type of testing may not be appropriate for all individuals (e.g., those with limited resistance training experience). An ideal strength test would be an assessment that is easy to administer on large groups, limits fatigue that could influence other aspects of testing or training, and is safe to perform regardless of age, sex, and relative skill level (Sheppard et al., 2013; West et al., 2011). A leg/back dynamometer (LBD) may provide a test that is easy to administer, while also being an affordable option for many practitioners.

The LBD has been used to assess strength in high school athletes (Lockie et al., 2023a; Lockie et al., 2023b; Wakely et al., 2022), university athletes (Najiah et al., 2021), and tactical personnel such as first responders (Dawes et al., 2019; Dawes et al., 2017; Lockie et al., 2020a; Lockie et al., 2020b). This test allows for maximal force exertion against an external resistance and dynamometry provides an efficient way to measure strength (Najiah et al., 2021; Ten Hoor et al., 2016). As a measure of validity, Najiah et al. (2021) found very large-to-near perfect relationships between the LBD (measured in kg) with the 1RM back squat ($p < 0.001$, $r = 0.877$) and deadlift ($p < 0.001$, $r = 0.984$) in male university athletes. Thus, the LBD provides a lower-body strength test that is simple to administer, while also being applicable to highly-trained or lesser-trained individuals.

However, some individuals may have a pulling strength that exceeds that of the typical leg/back dynamometer, which can be up to 299.37 kg (660 lbs) (Fabrication Enterprises Inc., 2023). A commercial crane scale could provide an affordable option while also having the value of a greater capacity than the typical LBD (up to 907 kg, or 2000 lbs) (Global Industrial™, 2023). However, there is no research that has investigated whether an adapted leg/back dynamometer (ALBD) that uses a commercial crane scale provides a valid and reliable measure of isometric leg/back strength.

Therefore, the purpose of this study was to determine the validity and reliability of an ALBD that used a commercial crane scale with a greater capacity than a typical LBD. The ALBD was compared to and correlated with the LBD to determine validity. A test-retest analysis was used to determine reliability of the ALBD metric. It was hypothesized that the ALBD would provide a valid and reliable measure of isometric leg/back maximal strength in physically-active individuals.

Methods

Experimental Approach

This study was a prospective, validation and test-retest reliability study, with procedures adapted from previous studies (Lockie et al., 2013; Najiah et al., 2021; Ten Hoor et al., 2016). Subjects completed three testing sessions. The first session was originally intended as a familiarization session (Courel-Ibáñez et al., 2020); sessions two and three were to be the test-retest sessions for the reliability analysis. The ALBD was compared to and correlated with the LBD to determine validity. Reliability was assessed by intra-class correlation coefficients, coefficient of variation (CV), and a three-way repeated measure analysis of variance (ANOVA). Both the LBD and ALBD were measured in kilograms (kg).

Participants

Fifty physically active people (age: 23.02 ± 3,43 years; height: 1.68 ± 0.11 m; body mass: 78.46 ± 14.63 kg), including 34 men (age: 22.76 ± 2.79 years; height: 1.72 ± 0.10 m; body mass: 82.03 ± 13.07 kg) and 16 women (age: 23.56 ± 4.56 years; height: 1.60 ± 0.05 m; body mass: 70.88 ± 15.27 kg) were recruited for this study. Participants self-reported whether they completed the minimum recommended physical activity for cardiorespiratory and musculoskeletal fitness as detailed by the American College of Sports Medicine

(Garber et al., 2011), and were free from injuries that could influence study participation. G*Power software was also used to confirm post hoc that the sample size of 50 was sufficient for a correlation, point biserial model, and ensured the data could be interpreted with a moderate effect level of 0.40 (Hopkins, 2004b), and a power level of 0.86 when significance was set at 0.05 (Faul et al., 2007). The institutional review board approved the study (HSR-22-23-334), all Participants received a clear explanation of the procedures. This included the risks and benefits of participation, and written informed consent was obtained. The study followed the recommendations of the Declaration of Helsinki (World Medical Association, 1997).

Measurements and Procedures

Participants completed three testing sessions. The first session was originally intended as a familiarization session (Courel-Ibáñez et al., 2020); sessions two and three were to be the test-retest sessions for the reliability analysis. Data was collected in three approximate 30-40-minute testing sessions which were separated by 48-72 hours depending on participant availability. Participants were informed to wear athletic clothing and shoes that they would typically use for training (i.e., sneakers). The same shoes and similar clothes were to be worn at all sessions. No supportive garments (e.g., wrist wraps, weight belts) were worn during any of the tests. All testing was conducted in the university's Human Performance Lab, which had rubberized flooring. Prior to testing in session one, participants signed an informed consent form and completed a physical activity readiness questionnaire. Height was measured using a stadiometer (Detecto, Webb City, MO, USA), and body mass was measured by an electronic digital scale (Model HBF-510, Omron Healthcare, Kyoto, Japan). After this, participants completed a dynamic warm-up that lasted approximately 8-10 minutes. All participants completed the same dynamic warm-up prior to all testing sessions, which comprised of skips with arm swing, side jacks with arm swing, lunge to rotation with hamstring stretch, pigeon stretch, A-Skips, cariocas, and five bilateral base drops with arm swing.

The procedures for this study were adapted from previous research (Lockie et al., 2013; Najiah et al., 2021; Ten Hoor et al., 2016). Participants alternated whether they completed the LBD or the ALBD first, such that it was evenly divided amongst the sample. The order of the LBD and ALBD was kept consistent across all sessions. As noted, the first session was originally intended to be a familiarization session (Courel-Ibáñez et al., 2020), where participants completed both the LBD and ALBD with the same procedures as that for the second and third sessions. For both the LBD and ALBD, participants completed two warm-up or practice pulls using the specific procedures for each device. This helped prepare the participants for the required maximal effort pulls, and also allowed the researchers to correct any flaws in technique (Nuzzo et al., 2011). Following this, participants completed three trials with either the LBD or ALBD, with rest times of 2 minutes allocated between attempts. The tests will be presented here as if the standard LBD was performed first. Nevertheless, the procedures used to set-up the participant for the strength test with either device was the same.

Standard Leg/Back Dynamometer

The standard LBD had an oversize base with a capacity of 299.37 kg (Fabrication Enterprises, Inc., New York, USA). The methods were adapted from previous research (Dawes et al., 2019; Dawes et al., 2017; Lockie et al., 2020a; Lockie et al., 2020b; Lockie et al., 2023a; Lockie et al., 2023b; Wakely et al., 2022). Participants were positioned so their arms were extended and both hands were on the handle positioned at the mid-thigh, with a knee flexion angle of approximately 110° (Figure 1). The knee angle was measured with a goniometer so that participants would be positioned in the same way for the second strength test. A countdown of "3, 2, 1, pull" was given to the participants before they initiated the pull. Similar instructions have been shown to produce optimal results for maximum force development in isometric pulls (Haff et al., 1997). Participants were to maintain proper spinal alignment and their feet flat on the base and pulled the handle upward as hard as possible by attempting to extend the hips and knees. The pull was held for approximately 5 seconds, with data recorded to the nearest kg.

Figure 1. Frontal (A) and sagittal (B) view of the set-up for the leg/back dynamometer test.

Adapted Leg/Back Dynamometer

The ALBD used a commercial crane scale (Global Industrial™, New York, USA) connected to a cable straight bar attachment and custom base. The crane scale had a capacity of 907 kg. Participants were set-up in the same position for the ALBD as for the LBD, with the same knee angle in the pull position (Figure 2). The exact same procedures for the LBD were also used for the ALBD. Three, 5-second pulls were completed for the ALBD, with data also recorded to the nearest kg.

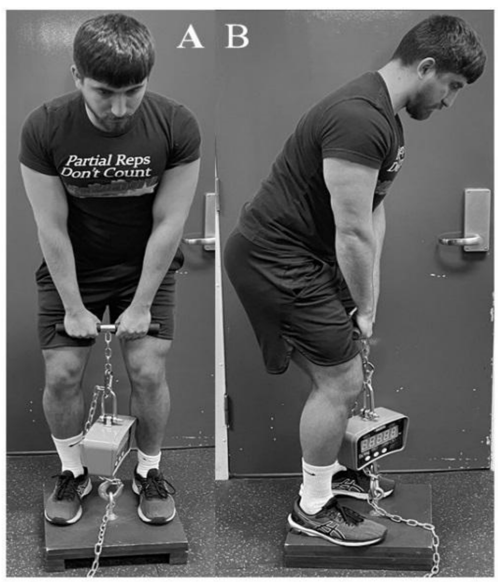

Figure 2. Frontal (A) and sagittal (B) view of the set-up for the adapted leg/back dynamometer test.

Statistical analyses

Statistical analyses were computed using the Statistics Package for Social Sciences (Version 29.0; IBM Corporation, New York, USA) and Microsoft Excel (Microsoft Corporation, Redmond, Washington, USA). Descriptive statistics (mean ± standard deviation [SD]; 95% confidence limits [CL]) were calculated for the LBD and ALBD data in each session. Males and females were combined in the sample. Normality of the data was evaluated by the Kolmogorov-Smirnov test and visual evaluation of Q-Q plots. Analysis was conducted on the average from the three trials for the LBD and LABD within each session, as well as the best trial (i.e., the trial with the maximum strength value). To assess agreement, the difference and average between the LBD and ALBD mean for each session were calculated with the intention of creating Bland-Altman plots (Doğan, 2018). One-sample t-tests were used to ascertain whether the difference between the LBD and ALBD means was statistically significant ($p < 0.05$) compared to 0 (i.e., no difference between the means). Further, paired samples t-tests ($p < 0.05$) were used to compare the average and maximum values for the LBD and ALBD to provide a measure of concurrent validity (Aung et al., 2020; Lockie et al., 2013). Effect sizes (*d*) were also calculated for the between-strength test comparisons, where the difference between the means was divided by the pooled SD (Cohen, 1988). A *d* less than 0.2 was considered a trivial effect; 0.2 to 0.6 a small effect; 0.6 to 1.2 a moderate effect; 1.2 to 2.0 a large effect; 2.0 to 4.0 a very large effect; and 4.0 and above an extremely large effect (Hopkins, 2004b). To further analyze validity, Pearson's correlations ($p < 0.05$) and regression were used to derive relationships between the LBD and ALBD. The correlation strength was designated as: an *r* between 0 to ±0.3 was small; ±0.31 to ±0.49, moderate; ±0.5 to ±0.69, large; ±0.7 to ±0.89, very large; and ±0.9 to ±1 near perfect for relationship prediction (Hopkins, 2006). Regression have been recommended for use in validity analyses (Hopkins, 2004a), and thus were included in this research.

Intra-class correlation coefficients (ICC) and CV were used to analyze reliability across the trials (single and average) within each session. The CV for the LBD and ALBD in each session was calculated as the standard deviation of the dataset divided by the mean, before being converted into a percentage (%). An ICC equal to or above 0.70 and a CV of less than 5% was acceptable (Baumgartner & Chung, 2001; Lockie et al., 2013). The differences between the sessions for the LBD and ALBD across the three testing sessions was assessed by a three-way repeated measures ANOVA ($p < 0.05$). If a significant between-session interaction was found, a Bonferroni post hoc adjustment for pairwise comparisons was implemented.

The usefulness of the LBD and ALBD was determined by comparing the typical error (TE) to the smallest worthwhile change (SWC) in kg for each test (Hopkins, 2004b). Within each session, TE was calculated for each variable via the formula $TE = SD \div (\sqrt{N})$, where *N* was the sample size of 50. The SWC was determined by multiplying the between-participant SD by 0.2, which is the typical small effect (Hopkins, 2004b), If the TE for either the LBD or ALBD was below the SWC, the test was 'good'; if the TE was similar to the SWC, the test was 'OK'; and if the TE was higher than the SWC, the test was 'marginal' (Hopkins, 2004b).

Results

The Kolmogorov-Smirnov data indicated all variables were normally distributed ($p = 0.053$-0.200), and visual analysis of the Q-Q plots confirmed this analysis. Table 1 displays the within-session comparisons between the average and maximum values for the LBD and ALBD. With regards to the one-sample t-test, all LBD and ALBD mean differences were significant ($p \leq 0.04$), which indicated a fixed bias between the LBD and ALBD. Thus, Bland-Altman plots were not created. The paired-samples t-tests confirmed these results, as the LBD recorded significantly higher average and maximum values when compared to the ALBD. In Sessions 1 and 2, all the differences between the LBD and ALBD had small effects ($d = 0.43$-0.58). In Session 3, the differences between the average and maximum LBD and ALBD values had moderate effects ($d = 0.89$ and 0.79, respectively). Nonetheless, the relationships between the LBD and ALBD, regardless of session, for both the average (Table 2) and maximum (Table 3) values were all significant ($p < 0.001$) and had an *r* above 0.9, indicating near perfect relationships. To this end, data from all three testing sessions was used to produce regression equations for both the average and maximum values. For both the average (Figure 3) and maximum (Figure 4) values, there was 94% explained variance.

Table 1. Comparisons between the leg/back dynamometer (LBD) and adapted leg/back dynamometer (ALBD) within the three testing sessions. Data reported as mean ± SD (95% CI). Intra-class correlation coefficients (ICC) for average and single measures and coefficient of variation (CV) for the session trials are also displayed.

	LBD	ALBD	*p*	*d*
Session 1				
Average (kg)	128.59 ± 38.33 (117.70-139.48)	122.87 ± 38.47* (111.94-133.80)	<0.01	0.58
Maximum (kg)	133.85 ± 38.72 (122.84-144.85)	129.28 ± 38.40* (118.20-140.36)	<0.01	0.43
$ICC_{Average}$	0.99	0.99		
ICC_{Single}	0.97	0.96		
CV (%)	4.64	5.94		
Session 2				
Average (kg)	129.71 ± 38.64 (118.73-140.69)	123.32 ± 36.29* (113.01-133.63)	<0.01	0.57
Maximum (kg)	134.36 ± 39.96 (123.00-145.72)	128.94 ± 37.28* (118.35-139.53)	<0.01	0.50
$ICC_{Average}$	0.99	0.99		
ICC_{Single}	0.98	0.97		
CV (%)	3.87	5.02		
Session 3				
Average (kg)	135.01 ± 39.29 (123.85-146.18)	128.83 ± 38.06* (118.02-139.65)	<0.01	0.89
Maximum (kg)	137.66 ± 39.72 (125.37-148.95)	132.22 ± 38.78* (121.20-143.24)	<0.01	0.79
$ICC_{Average}$	1.00	1.00		
ICC_{Single}	1.00	0.99		
CV (%)	2.11	2.82		

Table 2. Correlations between the average leg/back dynamometer (LBD) and adapted leg/back dynamometer (ALBD) trials recorded in Sessions 1-3 in college-aged men and women. All relationships were significant at p < 0.001.

	LBD Session 1	LBD Session 2	LBD Session 3
ALBD Session 1	0.97		
ALBD Session 2	0.90	0.96	
ALBD Session 3	0.95	0.96	0.98

Table 3. Correlations between the maximum leg/back dynamometer (LBD) and adapted leg/back dynamometer (ALBD) trials recorded in sessions 1-3 in college-aged men and women. All relationships were significant at p < 0.001.

	LBD Session 1	LBD Session 2	LBD Session 3
ALBD Session 1	0.96		
ALBD Session 2	0.91	0.96	
ALBD Session 3	0.96	0.97	0.99

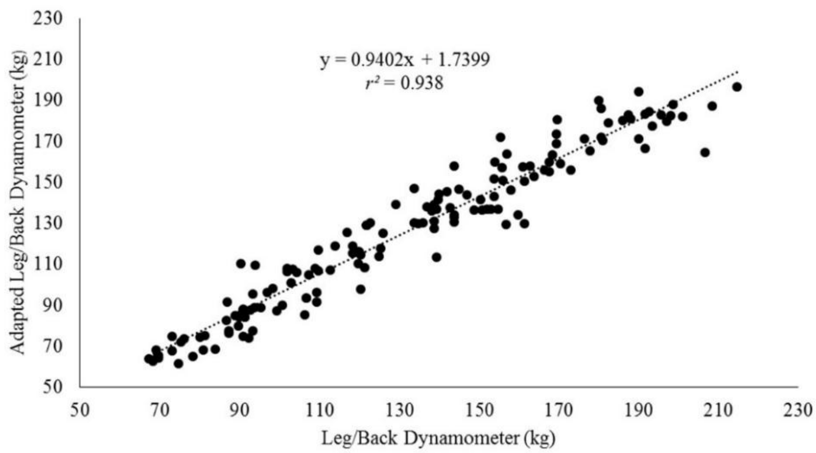

Figure 3. Regression for the average values recorded from 50 participants across three sessions from the leg/back dynamometer and adapted leg/back dynamometer.

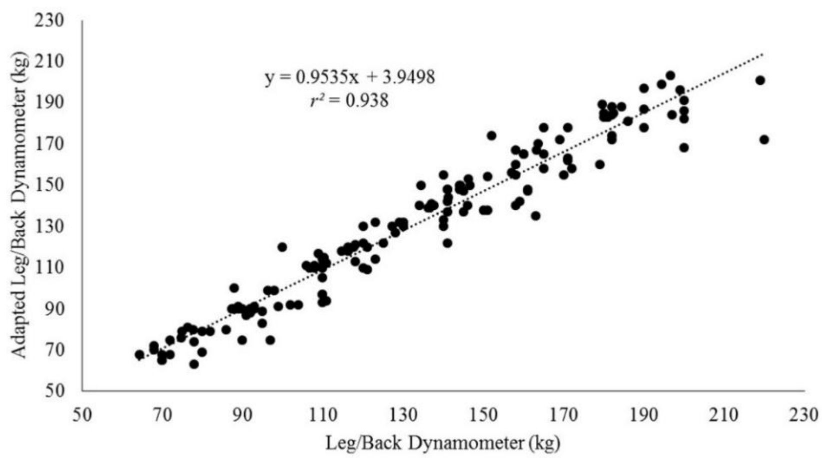

Figure 4. Regression for the maximum values recorded from 50 participants across three sessions from the leg/back dynamometer and adapted leg/back dynamometer.

In all testing sessions for both the LBD and ALBD, the ICCs for single or average trials were high (ICC ≥ 0.97; Table 1). For the CV, the LBD was below 5% in all testing sessions. For the ALBD, CV was approximately 6% in session 1, 5% in Session 2, and 3% in Session 3. There were notable results when comparing the average (Figure 5) and maximum (Figure 6) LBD and ALBD mean data. For the LBD, the main effects for session for the average ($F_{(2,48)} = 28.727$, $p < 0.001$, $\eta p^2 = 0.545$) and maximum ($F_{(2,48)} = 11.457$, $p < 0.001$, $\eta p^2 = 0.323$) LBD were significant. The average LBD for Session 3 was 4-5% significantly greater than that recorded in Sessions 1 and 2 ($p < 0.001$). This was also the case for the maximum LBD from Session 3; the value from these sessions were 2-3% significantly greater than Sessions 1 ($p < 0.003$) and 2 ($p = 0.008$). Similar results were observed for the ALBD, where the main effect for session was significant for average ($F_{(2,48)} = 22.365$, $p < 0.001$, $\eta p^2 = 0.482$) and maximum ($F_{(2,48)} = 7.548$, $p = 0.001$, $\eta p^2 = 0.239$) values. The Session 3 average ALBD value was 4-5% significantly greater than that recorded in Sessions 1 ($p < 0.001$) and 2 ($p = 0.002$). The Session 3 maximum ALBD value was 2% significantly greater than Session 1 ($p = 0.042$), but not Session 2 ($p = 0.089$). There were no significant differences between any LBD or ALBD values recorded in Sessions 1 or 2. The test usefulness data for all sessions is displayed in Table 4. Both the LBD and ALBD were deemed to be good tests regardless of session. All SWC values exceeded the TE.

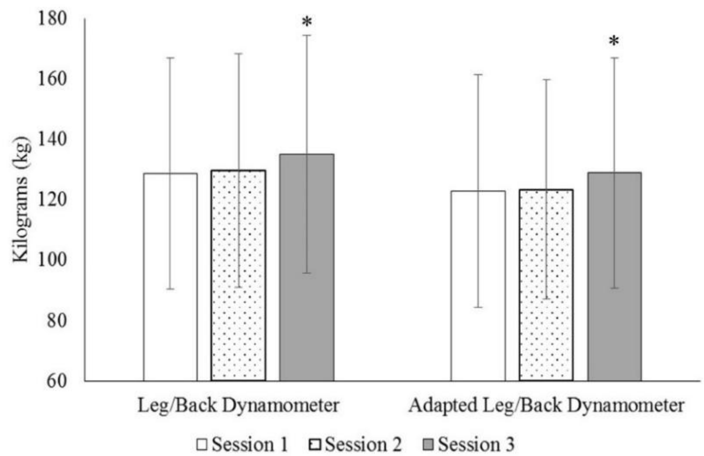

Figure 5. Between-session comparisons for average values recorded across three sessions from the leg/back dynamometer and adapted leg/back dynamometer (N = 50). *Significantly different from Sessions 1 and 2.

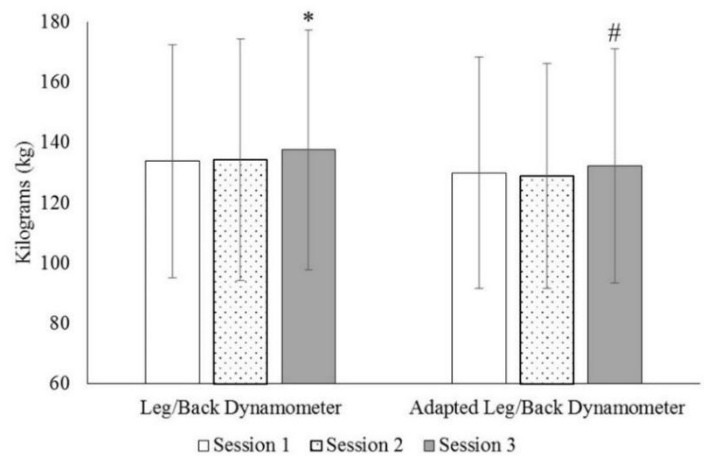

Figure 6. Between-session comparisons for maximum values recorded across three sessions from the leg/back dynamometer and adapted leg/back dynamometer (N = 50). *Significantly different from Sessions 1 and 2; #Significantly different from Session 1.

Table 4. Usefulness of the average and maximum leg/back dynamometer (LBD) and adapted leg/back dynamometer (ALBD) values from the three testing sessions when considering typical error (TE) and smallest worthwhile change (SWC).

	LBD		ALBD	
	Average	**Maximum**	**Average**	**Maximum**
Session 1				
TE (kg)	5.42	5.48	5.44	5.52
SWC (kg)	7.67	7.74	7.69	7.80
Test Rating	Good	Good	Good	Good
Session 2				
TE (kg)	5.46	5.65	5.13	5.27
SWC (kg)	7.73	7.99	7.26	7.46
Test Rating	Good	Good	Good	Good
Session 3				
TE (kg)	5.56	5.62	5.38	5.48
SWC (kg)	7.86	7.94	7.71	7.76
Test Rating	Good	Good	Good	Good

Discussion

This study determined the validity and reliability of an ALBD that used a commercial crane scale with a greater capacity than a typical LBD. Najiah et al. (2021) has previously acknowledged that the LBD provided a valid measure of lower-body maximal strength, with near perfect correlations shown with the 1RM back squat (r = 0.877) and deadlift (r = 0.984). Additionally, the LBD has been used as a strength testing tool within numerous populations (Dawes et al., 2019; Dawes et al., 2017; Lockie et al., 2020a; Lockie et al., 2020b; Lockie et al., 2023a; Lockie et al., 2023b; Najiah et al., 2021; Wakely et al., 2022). These studies helped support the use of the LBD as the standard for comparisons with the ALBD. The results indicated that there was a fixed bias which affected agreement between the LBD and ALBD, in that the values recorded from the ALBD were significantly lower than that for the LBD. The was shown by both the one-sample and paired samples t-tests. It is not surprising that ALBD tended to record lower values than the LBD, given the capacity for each device. The standard LBD had a limit of 299.37 kg, while the crane scale in the ALBD had a limit of 907 kg. Even a small crane scale is generally designed to tolerate much heavier loads than that could be exerted by a person (Eilon Engineering, 2022; Global Industrial™, 2023). The crane scale design could have affected the data recorded from the participants in this study, which resulted in smaller average and maximum strength metrics when compared to the LBD. Nevertheless, the results suggested that assuming the LBD was a valid measure of maximal strength (Najiah et al., 2021), the ALBD provided data different to the LBD.

The correlation data, however, provided some support to how the ALBD was measuring similar qualities to the LBD. There were near perfect, positive relationships between the LBD and ALBD. Although there are limitations to using correlations to assess validity (Doğan, 2018), the data did suggest that those participants who performed well in the LBD also performed well in the ALBD. Regression can also be valuable in validity analyses (Hopkins, 2004a). The regression equation developed between the LBD and ALBD had 94% explained variance (i.e., r^2 = 0.938) for both average and maximum values. A high r^2 value suggests better predictive ability for the regression equation (Chicco et al., 2021). These data suggest that based on the sample from the current study, LBD performance could be predicted from the ALBD, and vice-versa. This was true for both the average ($y = 0.9402x + 1.7399$) and maximum ($y = 0.9535x + 3.9498$) values recorded in this study. It should be noted that the fixed bias between the tests (i.e., the LBD recorded higher values than the ALBD) suggested that each test be considered separate to the other. However, given the relationships between the LBD and ALBD, predictive equations could be used by the practitioner as needed, with the acknowledgement of potential agreement or bias issues.

With regards to the reliability data, single and average ICC values were very high (above 0.90) and above the accepted standard in this study of 0.70 (Baumgartner & Chung, 2001; Lockie et al., 2013) in all sessions, which indicated good trial-to-trial reliability. The was also the case for the LBD when considering CV, where the CV was below 5% in all sessions. The CV for the ALBD was highest in session 1 at 5.95% and slightly above the accepted range for this study. However, the CV for the ALBD decreased in sessions 2 and 3 into the acceptable range of 5% or below. Thus, good inter-trial reliability can occur with either the LBD or ALBD.

The results did indicate some variation in average and maximum values across the sessions. The study featured three testing sessions, and originally the first session was intended to be a familiarization session (Courel-Ibáñez et al., 2020). These procedures followed that for RM strength testing. Following a systematic review of the literature, Grgic et al. (2020) stated that reliability in RM strength testing was similar between trained and untrained individuals, and familiarization may not have as big an impact as previously thought. Accordingly, it was decided that the first session would serve as a familiarization session, with the exact same procedures performed in this session as for the second and third testing sessions. Upon analysis of the data, it was found that the average and maximum data for both the LBD and ALBD were not significantly different between Sessions 1 and 2. However, the average and maximum LBD values from Session 3 were significantly greater than that recorded in Sessions 1 and 2. Similarly, the average ALBD value was significantly greater than Sessions 1 and 2, while the maximum ALBD was greater than Session 1. The actual differences were relatively small – between 2-5% for any of the significant comparisons. Nonetheless, these data may indicate that the participants may have become more familiar with both leg/back dynamometer tests by Session 3 and could produce higher values (Ploutz-Snyder & Giamis, 2001). In physically active men, Dias et al. (2005) suggested 2-3 practice sessions for bench press, back squat, and arm curl 1RM strength testing were needed to produce reliable results. Specific to an isotonic knee extension dynamometer strength test, Ploutz-Snyder & Giamis (2001) recommend 3-4 practice sessions for young women (~23 years of age), and 8-9 practice sessions for older women (~66 years of age). Nonetheless, Grgic et al. (2020) noted that excessive familiarization sessions are not practical, and in research, could lead to excessive dropout rates. Indeed, the study by Ploutz-Snyder & Giamis (2001) only featured 13 participants, far below that for the current study (N = 50). It is not known whether the values recorded from the LBD and ALBD would change over subsequent testing sessions. Grgic et al. (2020) did state that familiarization may be required for an exercise if the individual is not experienced with the movement used in a strength test. It is plausible to suggest that implementing two practice sessions for the leg/back dynamometer could allow for greater reliability in strength testing.

It should be noted it may not always be practical to conduct numerous practice testing or familiarization sessions. For example, and as noted, the LBD has been used to assess strength in first responders (Dawes et al., 2019; Dawes et al., 2017; Lockie et al., 2020a; Lockie et al., 2020b). Police officers and firefighters are notably time-poor (i.e., there is often limited time to perform extraneous fitness-related activities due to work demands) (Lockie et al., 2021), so there may be limited opportunities for practitioners to conduct fitness testing. Moreover, due to the risk of injury in these populations (Lockie et al., 2022), staff are often reticent to allow for multiple maximal strength testing sessions, so these may not always be possible. In these situations, what was particularly notable from the study results is that all average and maximum LBD and ALBD values were classified as being 'good' relative to their usefulness (Hopkins, 2004b), as the SWC exceeded the TE from each session. What this means is that the smallest notable performance change for either the LBD and ALBD exceeded the error associated with the test. Accordingly, if a practitioner sees in increase of 7-8 kg in the LBD or ALBD (the approximate SWC across all sessions), they can be confident that it is a real change in performance. Practitioners could use the LBD (or ALBD) with certain populations without specific familiarization, while recognizing the potential for improvements due to individuals becoming better at performing the test. Practitioners should carefully monitor their test results, so as to recognize whether any improvements are due to learning or training effects. Nevertheless, even without familiarization, both the LBD and ALBD are useful tests.

There are study limitations that should be acknowledged. Only one type of commercial crane scale was used for the ALBD, and it is certainly possible that different models would produce different results. This would affect the validity and reliability when compared to a standard LBD. The study utilized college-aged men and women. All participants were physical active, but inclusion criteria did not explicitly state that participants had to be resistance training (although that could be part of the physical activity completed by participants). Strength-trained people could present different results (Dias et al., 2005; Ritti-Dias et al., 2011), especially when considering the reliability measurements over the three sessions. Nonetheless, given that isometric leg/back strength testing is a viable often for populations that may not have long strength training backgrounds, such as high school athletes (Lockie et al., 2023a; Lockie et al., 2023b; Wakely et al., 2022) or first responders (Dawes et al., 2019; Dawes et al., 2017; Lockie et al., 2020a; Lockie et al., 2020b), the study sample is an applicable population. The sexes were combined in the sample for this study. As there can be performance differences in maximal strength tests when comparing men and women (Leyk et al., 2007; Lockie et al., 2020b; Reynolds et al., 2006), it is possible the relationships and predictive equations between the LBD and ALBD could vary by sex. Only three testing sessions were used, and performance in the LBD and ALBD seemed to improve. Despite potential impracticalities when using multiple familiarization or practice sessions (Grgic et al., 2020), It is not known how many testing sessions may be required before performance plateaus using either isometric strength testing device.

Conclusion

The study results indicated that when compared to the LBD, the ALBD recorded lower average and maximum strength values, which indicated a fixed bias relative to agreement. However, the LBD and ALBD were highly correlated. A regression provided prediction equations that explained 94% of the variance between the tests, so even with the fixed bias, a practitioner could predict a LBD value from the ALBD if it was required. The LBD and ALBD data were reliable, especially when considering the ICC and CV values within each testing session. However, the data also suggested that individuals new to the isometric strength testing could exhibit higher strength values when they become more familiar with the test. At least two familiarization or practice sessions could be used to prepare participants for an isometric strength test, whether using the LBD or ALBD. Nonetheless, both the LBD and ALBD were deemed useful tests across all sessions (i.e., SWC greater than the TE), so they both provide viable methods to measure isometric strength.

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Graduate Versus Undergraduate Interrater Reliability of the Landing Error Scoring System (LESS) and Less-Real Time

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Abstract

The study sought to determine if the LESS and LESS-RT scoring criteria are reliable when scored by graduate and undergraduate kinesiology students with minimal experience. Eleven graduate (7 male: 28.29 ± 3.251 years; 4 female: 28.00 ± 4.082 years) and 19 undergraduate (7 male: 21.57 ± 1.512 years; 12 female: 21.42 ± 4.870 years) students participated as raters. Raters with minimal (< 2 hours) or no experience with the LESS watched 30 videos and evaluated jump-landing mechanics using the LESS and LESS-RT across four sessions (two per criteria). A 4-way repeated measures ANOVA analyzed interactions among trials, groups, videos, and scoring sheets. Intraclass correlation coefficient (ICC), coefficient of variation (CV), and minimal difference (MD) values were calculated, with an alpha level of 0.05. ICC values for the whole group and undergraduates (R = 0.102 – 0.780) demonstrated "poor" to "good" reliability, while graduate students (R = 0.356 – 0.814) demonstrated "poor" to "excellent" reliability. The CV for the whole group, graduate, and undergraduate students (14.24 – 29.90%), were all above the 10% threshold thus, reliable. Prior experience with the LESS may impact the quality of assessment, therefore, providing a single training session could drastically improve the quality of ratings, even for novice raters.

Keywords: Fitness Testing, Jump-landing, Injury Prevention, Biomechanics, Assessment

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Introduction

The Landing Error Scoring System (LESS) is a movement competency screen that has been utilized in a variety of athletic and tactical populations to determine the potential for injury (Beutler et al., 2009; Padua et al., 2011; Padua et al., 2009). Specifically, the LESS is used to create a composite score based on different outcome measures that identify errors in jump-landing mechanics (Padua et al., 2011; Padua et al., 2009). In recreationally athletic populations, poor jump landing mechanics have been shown to correlate and predict an increased risk of noncontact anterior cruciate ligament injury (via receiver operator characteristic curve; 86% sensitivity, 64% specificity, $p \leq 0.005$) (Kernozek et al., 2008; Padua et al., 2015). Specific to tactical populations, the LESS has been used to determine deficiencies in landing mechanics among soldiers, as many soldiering tasks (i.e., exiting vehicles, traversing uneven terrain, jumping over walls and other obstacles) require proper jumping and landing technique to mitigate injury risk (Beutler et al., 2009; Mala et al., 2015; Orr et al., 2015; Scott et al., 2015). For these reasons, the LESS may be of value among first responders for reducing injury risks, as proper landing technique could also be important in many tasks (entering and exiting fire engines, maneuvering over curbs and barriers, etc.) required in this population. Despite the potential practical importance of using the LESS in tactical personnel such as first responders, greater analysis of how the LESS is scored by different individuals who may be assisting with occupational fitness testing is warranted.

The LESS composite score is derived from objective viewing of jump-landing mechanics. Therefore, consideration of who is scoring the LESS is important, as from a practical standpoint, the LESS may provide greater insight into musculoskeletal weaknesses and technical flaws that could be addressed via specific strength training interventions. Lower composite scores indicate fewer movement compensations, whereas higher scores reflect more errors and a greater probability of injury (Padua et al., 2015; Everard et al., 2018). Padua et al. (2009) introduced the LESS scoring criteria to include 17 items which each indicate a particular biomechanical compensation within the drop jump and landing patterns (e.g., knee valgus angle and trunk flexion angle at initial contact, hip and trunk flexion at the point of maximal knee flexion, symmetrical foot contact). Following the introduction of the LESS, an abbreviated scoring system consisting of 10 jump-landing characteristics, the LESS-Real Time (LESS-RT), was derived from the full assessment (Hanzlíková & Hébert-Losier, 2020). These assessments were introduced as an easily implementable tool for large-scale screening sessions that would provide the rater with a reliable measure of jump-landing mechanics (Padua et al., 2011; Padua et al., 2009).

Numerous studies have evaluated the reliability of the LESS and LESS-RT, showing good to excellent intrarater and interrater reliability (ICC range 0.71 to 0.96) (Padua et al., 2011; Padua et al., 2009; Everard et al., 2019; Markbreiter et al., 2015). These studies have often utilized individuals with advanced degrees (masters of science, athletic trainer certified, etc.), and with prior experience utilizing the LESS to complete these evaluations (Everard et al., 2019). However, students and interns from various backgrounds often collect data alongside coaches and academic staff, and this data may be utilized for practical application and research. If individuals without advanced degrees or prior experience with the LESS are administering and scoring the LESS and LESS-RT, this could impact the quality of data collected.

There is a paucity of research utilizing individuals without LESS exposure and advanced degrees to evaluate the LESS. Therefore, the purpose of this study was to determine if the scoring criteria of the LESS and LESS-RT are reliable when scored by graduate and undergraduate students in kinesiology degree paths, with minimal or no experience with the LESS. It was hypothesized that graduate students would demonstrate greater intrarater and interrater reliability than undergraduate students. It was also hypothesized that the LESS full sheet (LESS-full) would show greater consistency between groups than the LESS-RT.

Methods

Participants

Eleven graduate (7 male: 28.29 ± 3.2 years; 4 female: 28.00 ± 4.1 years) (3.64 ± 1.6 years of post-baccalaureate schooling) and 19 undergraduate (7 male: 21.57 ± 1.512 years; 12 female: 21.42 ± 4.9 years) students voluntarily agreed to participate as raters in this study. An a priori power analysis was conducted to determine that a sample size of 28 participants was necessary to achieve a power of 0.80 at an alpha level of 0.05 (Faul et al., 2007). All subjects were recruited from exercise science courses at the university where this study was conducted. Prior to the commencement of this study, all protocols were approved by the university's institutional ethics committee (ED-19-139-STW), and all participants completed and signed an informed consent document. This research was carried out fully in accordance with recommended ethical standards within the field of exercise science and the Declaration of Helsinki (Navalta et al., 2019; World Medical Association, 2001).

Measurements and Procedures

Lower extremity injury risk was assessed using the LESS, with procedures adapted from previous research (Beutler et al., 2009; Padua et al., 2011). Individuals from a local law enforcement and fire agency performed a double-leg jump from a 30 cm platform, landing with both feet, at a distance of approximately half their body height, and then immediately completed a maximal effort vertical jump (Beutler et al., 2009). Three individual trials were performed, which were recorded with a mounted camera (Sony CX405 Handycam, Sony Electronics Inc.; San Diego, California, USA; HD/60p frame rate) placed approximately one meter away from the landing position. The camera height was adjusted to the height of the participant's hip, and distance from the participant was increased or decreased to ensure that the participant's face was not captured during the trials (based on the height of the participant), while still maintaining full view of the anatomical points of interest in the LESS sheet. The first two jump trials were recorded from the frontal view, and the final trial was recorded from the sagittal view (Padua et al., 2009). Once trials were recorded, the videos were extracted from the camera via USB, and the unedited videos were placed into a PowerPoint presentation for rater scoring.

Graduate and undergraduate raters with minimal (< 2 hours) or no experience with the LESS watched 30 total video clips (three videos for each view of the individual's jump trial of the LESS) and evaluated jump-landing mechanics using the scoring criteria provided. Specific items and scoring criteria have been detailed previously in the literature (Padua et al., 2009; Padua et al., 2015). No limit was placed on the rater's ability to rewind, pause, slow down, or review videos as they were scoring. Video order and LESS scoring sheet version (LESS-full or LESS-RT) were randomized for all raters using an online number generator (www.random.org). Raters completed two scoring sessions per sheet (a total of four scoring sessions), separated by one week between sessions. The raters watched the 10 participants jump trials during each session, totaling in 20 ratings with the LESS-full, and 20 ratings with the LESS-RT. On average, raters completed each session in approximately 45 minutes.

All raters were instructed to follow the criteria on the LESS scoring sheet. No additional information was provided. The LESS-full was scored using 17-items that provided points for every landing error identified. The items included frontal- and sagittal-plane analysis, and identified errors associated with knee and hip angles, foot contact, displacement at the knee and hip, and overall impressions. The LESS-RT was scored using 10 jump-landing characteristics, derived from the original LESS criteria (Padua et al., 2011; Padua et al., 2009). The LESS-RT removes 7 items related to knee valgus at initial contact, knee and hip flexion angle at initial contact, hip and truck flexion at maximal knee flexion.

Statistical analyses

All statistical analyses were conducted using IBM Statistics Package for Social Sciences (IBM SPSS Inc., version 26; Chicago, Illinois, USA). A 4-way (trial [trial 1 vs trial 2] x scoring sheet [LESS-full vs LESS-RT] x video

[video 1-video 10] x student [undergraduate vs graduate]) repeated measures analysis of variance (ANOVA) was used to determine interactions among the variables, and to identify if main effects were present. Additionally, a pairwise t-test was conducted to determine if undergraduate and graduate raters scored significantly different on any of the individual videos. The test-retest reliability of each of the scoring sheets was calculated using an intraclass correlation coefficient (ICC, relative reliability) (2, k) model (Hopkins et al., 2009; Weir, 2005; Weir & Vincent, 2020). The ICC values were classified as "excellent" (0.80-1.0), "good" (0.60-0.80), or "poor" (<0.60) (Buckthorpe et al., 2012). The coefficient of variation (CV) was calculated using previously described equations to indicate a normalized measure of the standard error of the measurement, and the minimal difference to be considered real (MD) was calculated to examine individual differences for raters from trial 1 to trial 2 of each sheet (Weir, 2005; Weir & Vincent, 2020). A CV of <10% was used as an indication of acceptable absolute reliability (Weir, 2005); however, the overall reliability was characterized by accounting for the ICC value, CV, and MD. An a priori alpha level was set at 0.05 for all analyses.

Results

The trial x sheet x video x student ANOVA lacked significance ($F = 0.453$, $p = 0.905$, $p\eta^2 = 0.016$). However, a significant 3-way ANOVA for trial x video x student ($F = 2.178$, $p = 0.024$, $p\eta^2 = 0.082$) and a significant video x student interaction ($F = 4.004$, $p < 0.001$, $p\eta^2 = 0.125$) was observed. Follow-up pairwise comparisons among the 10 videos indicated that undergraduate students scored one of the 10 videos significantly lower, and one video significantly higher than graduate students ($t = -3.478$, $p = 0.002$; $t = 2.211$, $p = 0.036$, respectively).

The reliability statistics for each video for the LESS and LESS-RT scoring sheets are presented in Table 1 and 2, respectively. Using the LESS-full scoring sheet, the ICC values for the whole group ($R = 0.218 – 0.780$) and the undergraduate students ($R = 0.102 – 0.774$) demonstrated "poor" to "good" reliability, while the graduate students ($R = 0.356 – 0.814$) demonstrated "poor" to "excellent" reliability. However, the CV for the whole group (16.05 – 29.69%), graduate (14.24 – 29.90%), and undergraduate (15.87 – 29.48%) students were all above the 10% threshold to be considered reliable (Atkinson & Nevill, 1998).

Table 1. Intraclass correlation coefficient (ICC), standard error of the measurement (SEM), minimal difference to be considered real (MD), and coefficient of variation (CoV) for the Whole group, Graduate, and Undergraduate Students.

	Whole				Graduates				Undergraduates			
Video	**ICC**	**SEM**	**MD**	**CoV**	**ICC**	**SEM**	**MD**	**CoV**	**ICC**	**SEM**	**MD**	**CoV**
1	0.602	1.44	3.99	23.26	0.678	1.43	3.97	22.30	0.562	1.43	3.97	22.28
2	0.482	1.51	4.20	16.05	0.474	1.57	4.34	18.14	0.302	1.37	3.80	15.87
3	0.654	1.48	4.09	25.23	0.739	1.25	3.47	21.90	0.628	1.59	4.40	27.77
4	0.621	1.39	3.86	22.03	0.502	1.69	4.69	28.58	0.743	1.09	3.01	18.34
5	0.755	1.13	3.14	28.56	0.750	0.67	1.85	14.79	0.735	1.33	3.68	29.48
6	0.470	1.26	3.49	16.15	0.623	1.10	3.04	14.29	0.398	1.35	3.73	17.51
7	0.780	1.23	3.40	16.98	0.814	1.03	2.85	14.24	0.774	1.34	3.70	18.53
8	0.469	1.29	3.56	22.17	0.500	1.20	3.32	20.59	0.472	1.34	3.73	23.11
9	0.218	1.86	5.16	29.69	0.356	1.98	5.50	29.90	0.102	1.74	4.81	26.18
10	0.703	1.53	4.25	18.78	0.482	1.72	4.77	21.87	0.797	1.38	3.81	17.49
Average	0.575	1.41	3.91	21.89	0.592	1.36	3.78	20.66	0.551	1.39	3.86	21.66

Table 2. Intraclass correlation coefficient (ICC), standard error of the measurement (SEM), minimal difference to be considered real (MD), and coefficient of variation (CoV) for the Whole group, Graduate, and Undergraduate Students.

	Whole Group				Graduates				Undergraduates			
Video	ICC	SEM	MD	CoV	ICC	SEM	MD	CoV	ICC	SEM	MD	CoV
1	0.355	1.17	3.24	22.83	0.108	0.85	2.37	18.07	0.392	1.31	3.62	24.45
2	0.471	1.16	3.22	16.50	0.439	0.88	2.43	11.03	0.380	1.26	3.50	19.34
3	0.384	1.07	2.97	22.44	0.349	1.02	2.83	21.01	0.410	1.11	3.08	23.58
4	0.556	1.16	3.22	24.59	0.339	1.14	3.16	21.63	0.653	1.10	3.05	25.03
5	0.281	1.29	3.58	40.17	0.380	0.70	1.94	27.03	0.218	1.51	4.19	42.25
6	0.501	1.08	3.00	16.54	0.123	0.96	2.66	14.76	0.622	1.10	3.05	16.72
7	0.287	1.28	3.55	22.59	0.547	1.05	2.90	18.13	0.177	1.39	3.85	24.81
8	0.542	1.22	3.37	25.26	0.746	0.78	2.15	15.39	0.487	1.40	3.89	29.96
9	0.501	1.13	3.14	21.48	0.400	0.83	2.29	18.76	0.451	1.24	3.43	21.47
10	0.469	1.30	3.59	18.84	0.532	1.24	3.44	16.35	0.387	1.31	3.63	20.20
Average	0.435	1.19	3.29	23.12	0.396	0.94	2.62	18.22	0.418	1.27	3.53	24.78

For the LESS-RT scoring sheet, the whole group (R = 0.287 – 0.556) demonstrated “poor” reliability (Buckthorpe et al., 2012). However, the graduate (R = 0.108 – 0.746) and undergraduate (R = 0.177 – 0.622) students demonstrated “poor” to “good” reliability (Buckthorpe et al., 2012). Similar to the LESS-full score sheet, the CV for the whole group (16.50 – 40.17%), graduate (11.03 – 27.03%), and undergraduate (16.72 – 42.25%) groups were above the 10% threshold to be considered reliable. Lastly, 10.5% of undergraduate subjects exceeded the MD test-retest for the LESS-full scoring sheet (MD = 3.86 ± 0.47; range: 3.01 – 4.81), and 7.9% exceeded the MD for the LESS-RT scoring sheet (MD = 3.53 ± 0.39; range: 3.05 – 4.19) across all ten videos (range for individual videos: 0-21% and 0-16%, respectively). Additionally, 10% of graduate subjects exceeded the MD for test-retest for the LESS-full sheet (MD = 3.78 ± 1.08; range: 1.85 – 5.50), and 18% exceeded the MD for the LESS-RT sheet (MD = 2.62 ± 0.47; range: 1.94 – 3.44) across all ten videos (range for individual videos: 0-36%).

Discussion

These data show that both undergraduate and graduate students were generally unreliable with scoring on the LESS and LESS-RT, with few individual exceptions. This could have been due to several factors, however minimal experience with this scoring criteria most likely contributed. A majority of the raters in this study did not exceed the MD for each video (82-91% of raters), suggesting more reliable scoring, however individual exceptions were observed. Ideally, with the use of a scoring system such as the LESS, it is desired that raters do not exceed the MD, as the MD indicates differences, and consistency is preferred. Overall, undergraduate students were slightly less reliable than graduate students that participated in this study, with both groups exceeding the 10% CV threshold.

The scoring sheets for the LESS and LESS-RT did not show high levels of reliability within this sample of raters. The LESS-Full sheet was shown to be slightly more reliable between the groups of raters (R = 0.575 ± 0.169) than the LESS-RT sheet (R = 0.435 ± 0.101). It should be noted that in previous research evaluating the validity of the LESS against motion capture (considered the gold-standard), certain items within the scoring criteria showed poor and moderate agreement with motion capture (Onate et al., 2010). Based on these findings the investigators concluded that the validity of the LESS was most likely item dependent. Additionally, studies that compare novice versus expert rater reliability with the LESS have often reported small sample sizes, or provide training to the novice raters prior to scoring the task (Padua et al., 2011; Hanzlíková et al., 2020; Markbreiter et al., 2015; Onate et al., 2010). These factors could have contributed to the lower reliability between sheets, as well as the reliability of the rater groups.

This study was not without limitations. Namely, a reference rater that has shown excellent reliability with the scoring sheets was not utilized when analyzing the raters' reliability. Without a reference, it is unclear whether any raters in this study were accurate with their scoring, and any raters that demonstrated acceptable reliability could have been incorrect with their scoring across all videos and sheets consistently.

To the authors' knowledge, this is the first study to assess the inter- and intra-rater reliability of the LESS and LESS-RT among novice raters (minimal/no experience or training with the LESS or LESS-RT) consisting of university students. As exercise science students are often recruited to assist with large-scale testing and assessment for both athletic and tactical populations, it is imperative to provide training and/or experience with the screens administered. Prior experience or practice with the LESS, as these data suggest, may be the limiting factor in the quality of assessment being graded. Regardless of the education level of raters, experience with the screen may have affected the overall reliability observed. Therefore, providing a single training session (as short as one hour; Onate et al., 2010) could drastically improve the quality of ratings, even from novice raters.

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Conflict of interest: All authors declare that they have no conflict of interest relevant to the content of this article.

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Original article

Effect of Acute Beetroot Supplementation on Exercise Performance of CrossFit® Male Athletes: Randomized, Double-blind, Placebo-Controlled Crossover Study

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Abstract

The study aimed to evaluate the effect of beetroot supplementation on the number of repetitions in the Cindy test of male athletes who practice CrossFit® to improve their exercise performance. Twenty male CrossFit® athletes (age = 28 ±3 years, height = 1.71 ± 0.2 m, weight = 72.2 ± 4.2 kg) were included in a randomized, double-blind, placebo-controlled and crossover study. The participants consumed a beetroot supplement (515 mg (8.24 mmol) of nitrate) or placebo (starch) 90 min before starting the Cindy workout. Student's t-tests for paired samples were used to compare the performance between the beetroot supplement and placebo conditions and to examine for a learning effect between the first and the second sessions. No significant differences were found in performance between the beetroot supplement and the placebo conditions (17.4 ± 2.7 vs. 16.7± 2.3 rounds, t = 1.48, p = 0.078). However, a significant learning effect was determined between the first and the second session (16.6 ± 2.4 vs. 17.5± 2.6 rounds, t = 1.94, p= 0.034). Overall, the intake of 515 mg of beetroot nitrate (8.24 mmol) before a Cindy workout did not increase the number of repetitions performed. More studies are needed to confirm whether nitrate in beetroot can be used as an effective performance improvement strategy in CrossFit® male athletes, considering that a learning effect could be present in the practice of CrossFit® workouts.

Keywords: Beetroot, Dietary nitrate, Exercise performance, CrossFit, High-intensity functional training

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Introduction

CrossFit® has been characterized as a type of high-intensity training, with constant variability of functional movements that leads to improved physical conditioning. The exercises performed are usually high-intensity with little-to-no rest periods between sets, combining strength and endurance exercises such as running, Olympic weightlifting, and body weight movements (Dos Santos Quaresma et al., 2021). The number of people competing in CrossFit® games has grown considerably in recent years (CrossFit LLC, 2024). Similar to athletes in other sports, CrossFit® athletes report using a variety of nutritional supplements to enhance athletic performance (de Souza et al., 2021). Dietary nitrate is a popular nutritional supplement which has been shown to have positive effects on exercise performance after consumption (Hlinsky et al., 2020; Senefeld et al., 2020).

Dietary nitrate, found abundantly in vegetables such as beetroot, spinach, and lettuce, is converted in the body to nitric oxide (NO) via the enterosalivary nitrate-nitrite-NO pathway (Liu et al., 2023; Morou-Bermudez et al., 2022). Nitric oxide is known to play a crucial role in regulating blood flow, muscle contractility, and mitochondrial function, all of which are critical to athletic performance (Gantner et al., 2020; Jones et al., 2018; Pappas et al., 2023). Several high-quality systematic reviews and meta-analyses have explored the performance-enhancing benefits of dietary nitrate, the findings of which support that dietary nitrate supplementation, mostly in the form of concentrated beetroot juice, can improve muscle power (Coggan et al., 2021), single or repeated bouts of high-intensity exercise (Alsharif et al., 2023), and endurance exercise performance (Gao et al., 2021).

However, CrossFit® is a unique sports modality that's performance is determined by strength, endurance, flexibility, and body composition (Hollerbach et al., 2021; Tibana et al., 2021), and is performed through a variety of time domains and varying intensities. To date, very few studies have investigated the effects of dietary nitrate on exercise performance specific to CrossFit® (Garnacho-Castano et al., 2022; Kramer et al., 2016). Kramer et al. (2016) evaluated the effect of a 6-day intake of potassium nitrate (8 mmol·d^{-1}), on CrossFit® performance (Kramer et al., 2016). Peak power was improved during a Wingate test, but there were no improved elements of strength or endurance in male CrossFit athletes (Kramer et al., 2016). This is perhaps unsurprising given that the final nitrate dose was consumed ≥24 h before performance testing, which is not in line with expert consensus that recommends the final dose ingested 2–4 h pre-exercise in chronic supplementation regimes (Shannon et al., 2022). On the other hand, Garnacho-Castaño et al. (2020) found that acute beetroot juice supplementation (~ 12.8 mmol of nitrate) 3 hours pre-exercise improved the number of repetitions of wall balls and back squats performed with rest. A limitation of these studies is that they did not adopt an established common benchmark workout typically used in CrossFit® but rather characteristic exercises.

Certainly, acute supplementation is more favorable to athletes as it is more cost-effective and practical however based on current research there is limited evidence to support the use of dietary nitrates as an ergogenic supplement for CrossFit®-specific performance. In this context, the aim of this study was to investigate the effects of acute nitrate supplementation on a common benchmark workout in CrossFit® used to track performance improvements. According to previous investigations demonstrating performance improvement in high-intensity intermittent exercise with beetroot supplementation, it was hypothesized that after the intake of 515 mg (8.24 mmol) of nitrate contained in beetroot supplement, the number of rounds performed during the CrossFit® workout test would increase, compared to the number of rounds completed performing the same CrossFit® workout test, but under placebo condition.

Methods

Design and participants

Twenty male CrossFit® athletes took part in the study. The present study used a randomized, double-blind, crossover design and was approved by the bioethics committee of Cuauhtemoc University to carry out the research, with the code UC001-24. All participants were informed of the protocol and the risks that could present after consumption of the supplement, informed consent was obtained, and a written privacy notice was provided to each person to obtain their approval to participate in the present study. Inclusion criteria were: 1) male between 18 and 40 years of age; 2) at least 6 months of CrossFit® experience; 3) who did not consume supplements of any kind, except protein, or any medication; 4) who were not allergic to beetroot; and 5) without any diagnosed diseases. The sample size was based on previous similar studies (Oliveira et al., 2023; Stein et al., 2020; Ziyaiyan et al., 2023) resulting in a total of 20 participants, who were needed to determine the effects of beetroot supplementation for CrossFit® athletes. For this study, no instructions were given on diet, alcohol, and caffeine consumption, because these values were not standardized.

Measurements and Procedures

The study began with an interview with the volunteers to verify the selection criteria, in addition to explaining the protocol, the Cindy test and the risks that could occur during the protocol. Once informed, all participants signed the privacy notice and the informed consent form in both English and Spanish, thus establishing themselves as study volunteers.

During the screening visit, measurements were taken according to ISAK L1, to estimate the somatotype of the participants. Weight was determined using a digital scale (HBF-514C, Tanita, Japan). Height was measured with a stadiometer, and skinfolds were measured with a picometer (Slime Guide, USA). In the first testing visit, participants were randomized to consume either a beetroot supplement or a placebo. To determine the order of treatment (placebo and then beetroot vs. beetroot and then placebo), participants were randomly assigned using an Excel sheet, with odd numbers being placed into the placebo condition and even numbers being placed into the beetroot condition for the first testing visit (placebo then beetroot: n = 10; beetroot then placebo: n = 10). The project leader was the only investigator who was aware of the randomization of the supplement and placebo; therefore, he was not present during the Cindy test. The volunteers remained blinded throughout the study as well as the researchers responsible for the outcome measurements and the data analysis.

Participants began a self-selected warm-up 60 min after the consumption of the pill(s). Participants began the CrossFit® workout Cindy 90 min after the consumption of the pill(s). The time, 90 min, was selected based on the recommendations of a systematic review evaluating evidence from 23 clinical trials investigating the effect of beetroot supplementation on cardiorespiratory endurance in athletes (Dominguez et al., 2017). The training took place at the facilities of the Universidad Cuauhtémoc Aguascalientes, in an area without a roof, with shade. Each participant performed the workout alone, with no clock or timing device visible to them. CrossFit® training music was played for the participants and was consistent for all of them during their visits. The Cindy workout was chosen because it is standardized by CrossFit® and has been used previously in research (Oliveira et al., 2023; Stein et al., 2020; Ziyaiyan et al., 2023). Participants completed as many rounds as possible of 5 pull-ups, 10 push-ups and 15 squats in 20 minutes. The ranges of motion were established under CrossFit® criteria: kipping was allowed for the pull-ups; push-ups were performed on the toes, with the subject lowering the body straight down until the chest touched the ground and then pushed back up until their elbows locked; squats required subjects to reach full knee and hip extension at the top of each repetition and the hip crease to be below the knee at the bottom of each repetition (Stein et al., 2020). A trainer acted as a judge to measure the movements of the test for each repetition. Repetitions that did not meet movement standards were not counted, and participants were provided with feedback to meet the movement standards. CrossFit® performance was the total number of repetitions completed in 20 min.

Participants were given a post-exercise survey to determine if they perceived an effect from the supplement given (yes/no). A minimum of two weeks were considered for the washout. Participants returned to the University after 2 weeks (wash-out period) (Wylie et al., 2016) of taking the pill(s) and consumed the opposite of the first visit (placebo n = 10; beetroot n = 10) and followed the same test guidelines. After completion of the trial, contact was maintained with participants so that they could report any side effects from taking the pill(s). The experimental design is illustrated in Figure 1 and CONSORT flow chart is shown in Figure 2.

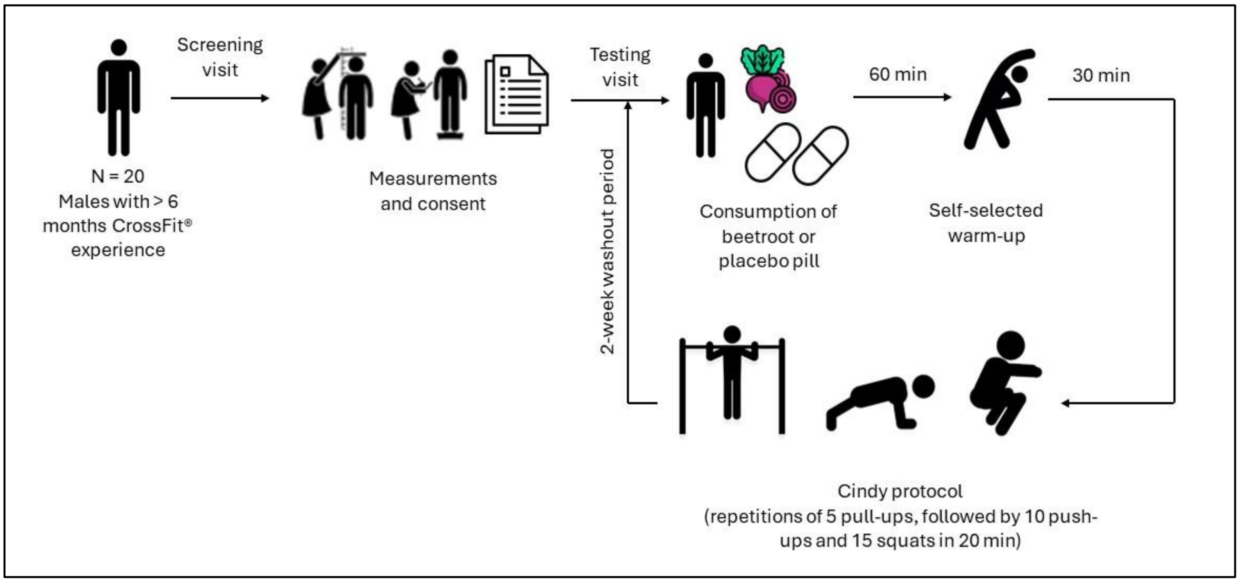

Figure 1. Experimental design.

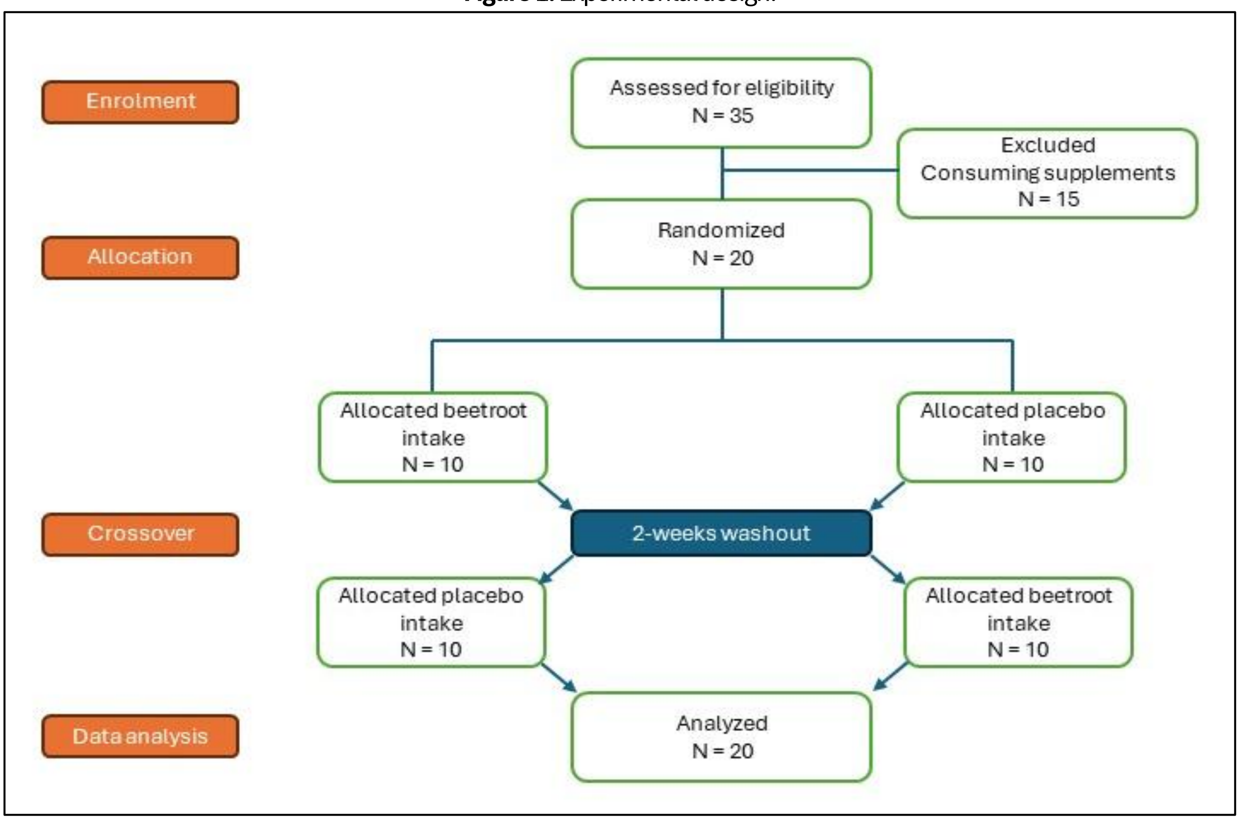

Figure 2. CONSORT flow diagram.

Beetroot supplement and placebo

The supplement used in the protocol was pills of the brand FUTUREBIOTICS with a beetroot content of 515 mg of nitrate (8.24 mmol), which was analyzed using the spectrophotometric technique to determine the amount of nitrates (Brzezinska-Rojek et al., 2023). The placebo was prepared in the Nutrition laboratory of the Universidad Cuauhtémoc Aguascalientes, using 0.4 g of starch and 3 drops of #40 (E-129) and #3 red dye (E-127) in conjunction with two drops of pink vegetable (after the mixture of yellow #3 (E-122) and #6 (E-110), blue #1 (E133) and #2) dye per tablet until the coloration identical to the supplement was achieved.

Statistical analyses

Data were analyzed with JAMOVI software. The normality assumption was tested for using the Shapiro-Wilk test ($p = 0.736$). Paired samples t-tests were used to determine differences between the nitrate and placebo conditions in the total numbers of repetitions. Taking into account the trial order, an additional paired samples t-test was used to determine if a learning effect was present between the first (visit 1) and second sessions (visit 2), irrespective of treatment group (Stein et al., 2020). Descriptive data are provided as mean ± standard deviation. The magnitude of treatment effects (ES) were estimated with Cohen's D and classified as "trivial" (<0.19), "small" (0.20–0.49), "moderate" (0.50–0.79), and "large" (>0.80) (Sullivan & Feinn, 2012). The level of significance was set at $p < 0.05$.

Results

All the recruited participants successfully completed the trial, and their data were included in the analysis. Participants age ranged from 19 − 44 years and BMI 18.2 − 29.2 kg/m^2, with varying CrossFit® experience ranging between 10 months to 9 years (108 months) (Table 1).

Participants performed between 6 to 31 rounds (180 to 930 repetitions) upon consuming beetroot supplement, which was similar to the range of rounds (6 to 28 rounds; 180 to 840 repetitions) upon placebo intake (Table 1). The t-test did not show significant differences between beetroot supplement and placebo conditions for CrossFit® performance, considering the number of rounds of a Cindy workout for 20 minutes (17.4 ± 2.7 vs. 16.7± 2.3 rounds, p= 0.078). A significant learning effect was detected between the first and second sessions (16.6 ± 2.4 vs. 17.5 ± 2.6 rounds, p= 0.034). As seen in Figure 3, the means of both conditions were similar; the average of 0.7 more rounds completed (ES = 0.28; small effect) in the supplement condition was not statistically significant. A significant learning effect was observed, with higher performance in session 2 (Figure 4). No athlete reported any effect after the beetroot supplement intake. Otherwise, two participants (10 %) reported increased activeness after the placebo intake.

Table 1. Athlete's demographics.

Variables	Mean	SD
Age (years)	28	7
Weight (kg)	72.2	9.8
Height (cm)	170.9	4.5
BMI (kg/m^2)	24.7	3.2
CrossFit® Experience (months)	36.2	30.5

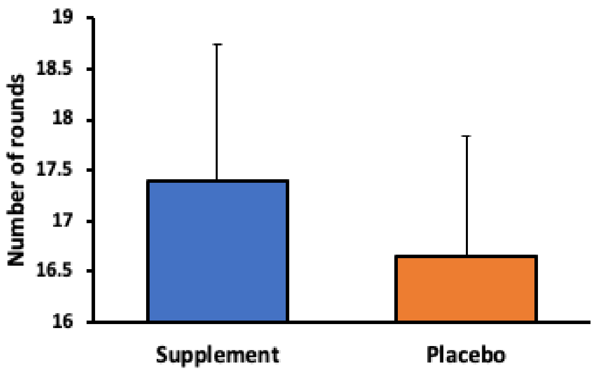

Figure 3. Number of rounds completed (mean ± standard deviation) by participants in Cindy protocol after consumption of supplement (beetroot powder) and placebo.

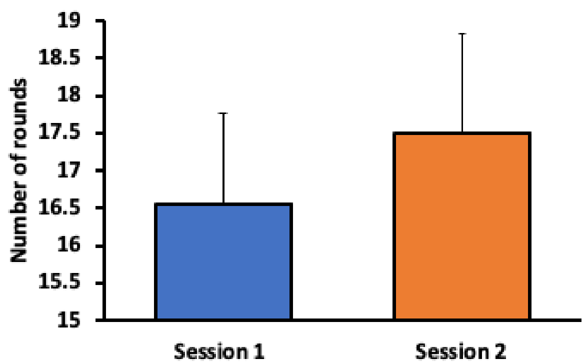

Figure 4. Number of rounds completed (mean ± standard deviation) by participants in Cindy protocol during the first session (testing visit 1) and second session (testing visit 2).

Discussion

This study examined differences in CrossFit® performance after acute nitrate supplementation compared to placebo among trained men. Contrary to our initial hypothesis, the results indicated no significant improvement in performance metrics, specifically the number of rounds completed in the "Cindy" protocol, following ingestion of beetroot powder compared to a placebo. The reason for this could be manifold including the type of supplement, dosing regime, and exercise performance metrics used in the current study.

In contrast to the current study, previous research has documented performance enhancements following beetroot supplementation in sporting activities with varying physiological demands (Alsharif et al., 2023; Coggan et al., 2021; Gao et al., 2021). While the dose used in the current study is consistent with current recommendations (8–16 mmol) (Shannon et al., 2022), it should be acknowledged that most prior research has utilised concentrated beetroot juice rather than tablets. Therefore, the different food matrices and processing methods of the supplements might account for the discrepancy between our findings and the findings of others. Moreover, only two other studies have investigated the acute effects of dietary nitrate on CrossFit® performance (Garnacho-Castano et al., 2020; Garnacho-Castano et al., 2022). Unlike the current study, Garnacho-Castaño et al. (2020) reported beetroot juice (~ 12.8 mmol of nitrate) improved the number of wall ball shots and full back squats completed with a 3-min rest, but not when no rest was given. These data suggest that nitrate supplementation could benefit CrossFit® requiring aerobic energy production, where enhanced blood flow and oxygen delivery play crucial roles. This is further supported by the reported reduced oxygen cost during the rest period and back squats with the beetroot (Garnacho-Castano et al., 2022). Apart from the higher dose (12.8 vs 8.3 mmol) that study also had a longer absorption period (3 vs 1.5 hours) as compared to our study which might account for the differences. With regards to the pharmacodynamics of nitrate, after ingestion of beetroot plasma nitrate peaks 1-2 hours postprandial, whereas plasma nitrite peaks 2-3 hours as it is recycled to the mouth before conversion by nitrite-producing oral bacteria (Bryan et al., 2022; Wylie et al., 2016) . Given that nitrite is the precursor to NO, the absorption period in the current study was likely insufficient to allow the maximum physiological benefits.

Other than the type of supplement and dosing regime, the exercise protocol could potentially be a key factor affecting the supplementation efficacy investigations. Our study assessed CrossFit® performance via “Cindy”, which has been widely adopted in research (Oliveira et al., 2023; Stein et al., 2020; Ziyaiyan et al., 2023), allowing for meaningful comparisons. In agreement with the current study, previous studies have found no effect of acute caffeine (Stein et al., 2020), caffeine with sodium bicarbonate (Ziyaiyan et al., 2023), and capsiate (Oliveira et al., 2023) supplementation on the “Cindy” protocol, despite the widely documented ergogenic effects. Thus, while “Cindy” represents an ecologically valid measurement of CrossFit® performance, it is possible that this performance metric is not sensitive enough to nutritional supplementation. Moreover, we found a significant learning effect between the first and second sessions, irrespective of the supplementation group, even though participants were familiar with CrossFit®. These findings are consistent with Stein et al. (2020) who also reported a learning effect, likely due to participants becoming more familiar with the specific demands of the CrossFit® workout used in the study. This learning effect is important to consider as it may have masked any subtle effects of beetroot supplementation. Future studies should consider the sensitivity of the performance measure and suitable familiarization protocols to eliminate potential learning effects so that evidence-based recommendations on supplement use for CrossFit® can be made.

This study is not without limitations, which should be considered when interpreting the findings. The detection of a learning effect suggests that the study design might have inadvertently introduced a variable that confounded the results. While this learning effect reflects natural improvements over time, it complicates the ability to isolate the effects of the beetroot supplementation. Additionally, the sample size, although adequate for the analysis, may not have been large enough to detect subtle effects of beetroot on performance. Furthermore, individual variability in response to beetroot supplementation, due to factors such as baseline training status, could have contributed to the null findings. Finally, the specific CrossFit® workout chosen for this study, while representative, might not encompass the full spectrum of CrossFit® activities, potentially limiting the generalizability of our results.

Conclusion

The findings of this study indicate that the intake of 515 mg (8.3 mmol) of beetroot nitrate, 90 minutes before a Cindy workout, does not improve CrossFit® performance. More studies are needed to confirm whether nitrate in beetroot can be used as an effective performance improvement strategy in CrossFit® male athletes since a learning effect was found for the workout Cindy. Future research should examine a learning effect in the practice of CrossFit® workouts.

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Review article

Physical Activity and Mental Health During the COVID-19 Pandemic

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Abstract

Objective: This review explores the complex relationship between physical activity, mental health, and specific challenges arising from the COVID-19 pandemic. The aim is to analyze changes in physical activity patterns, psychological effects of restrictions, and explore innovative approaches to maintaining an active lifestyle during the pandemic. A systematic literature review of five databases (PubMed, Embase, CINAHL, SPORTDiscus, and Web of Science) was conducted against inclusion criteria. Inclusion criteria involved research providing relevant insights into changes in physical activity and their impact on mental health. This review identified increased awareness of the importance of maintaining physical activity during the pandemic. Changes in exercise patterns and their impact on mental health have been observed. The analyzed research consistently indicates a link between physical activity and mental health during the COVID-19 pandemic, emphasizing the importance of promoting physical activity as a means of preserving mental health during periods of social distancing and lifestyle changes. Further research and implementation of targeted public health interventions are crucial to supporting population health during the pandemic. Research clearly demonstrates the importance of physical activity in maintaining mental health during the COVID-19 pandemic and in daily life. Further promotion of physical activity and the development of tailored public health strategies are essential to support population well-being.

Keywords: Physical activity, mental health, COVID-19 pandemic, isolation

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Introduction

The relationship between physical activity and general health and well-being and therefore mental health as well, is a topic that has occupied the attention of scientists for long time (e.g., Smith. & Brandt. 1979; Taylor et al., 1985; Raglin, 1990). Physical activity has a positive effect in the prevention but also the therapy of various diseases such as heart diseases (Morris, 1990), hypertension (Pescatello et al., 2004), diabetes (Manson et al., 1992), osteoporosis (Carter et al., 2002), and similarly. Not only does it contribute to an increased quality of life through the described positive effect on health status, physical activity has a positive effect in the prevention and treatment of psychiatric diseases such as depression or anxiety (Dimeo et al., 2001; Dunn et al., 2001; Leppämäki, 2002). More over physical activity helps in the relief symptoms of various associated with frequent changes or consistently low mood levels such as conditions fibromyalgia (Gowans et al., 2001;), nicotine abstinence (Masiero et al., 2020) or menopause (Slaven, & Lee, 1997). Physical activity has a positive effect on mental health throughout the entire life course, from children and adolescents (Biddle, & Asare, 2011; Herbert, 2022) to adults (Paluska, & Schwenk, 2000) and the elderly (Hemmeter, & Ngamsri, 2022) populations. Therefore, regular physical activity is recommended as a means of improving the overall level of public health and mental health as well (Pate et al., 1995) by the most reputable institutions dealing with the preservation and improvement of public health.

However, the vast majority of mentioned studies deal with the relationship between physical activity and mental health in everyday life. Within the challenges posed by the COVID-19 pandemic (Hanaei et al., 2022) the relationship between physical activity and mental health takes on new dimensions to explore. The global crisis, marked by uncertainty, restrictions, fear and changes in daily life, represents a radical change in circumstances in relation to the daily routine. For our topic, the increased level of stress and pressure on mental health brought by the pandemic (Chen, et al., 2021) is primarily important. Furthermore, impact of the measures to fight the pandemic, the lockdown above all, on the reduced possibility of movement and physical activity (Wunsch et al., 2022) is also an important new factor. Finally, one of the main factors by which physical activity has a beneficial effect on mental health is actually the social interaction and support that physical activity brings with it (Ransford, 1982; Peluso & Guerra de Andrade, 2005), which was also significantly reduced during the pandemic. Because of the entire above, Covid 19 pandemic revived the question of the relationship between physical activity and mental health in such specific conditions, which resulted in increased activity of researchers when it comes to this topic. This is why space for systematization of the results of current studies, as well as their comparison with studies of the connection between physical activity and mental health before the pandemic is wide open. Understanding this dynamic is not only challenging from a scientific perspective but also holds practical significance for the development of strategies and interventions aimed at preserving mental health in the context of pandemic conditions.

Through a systematic review of available literature and relevant empirical data, this review aims not only to expand theoretical understanding of their interconnection but also to identify key implications that can contribute to improving individuals' well-being in these challenging times. Through critical review, key findings are expected to be discovered to inform further support strategies and adaptations for preserving integral health during and after the pandemic period.

Methods

Design and participants

In the process of collecting relevant literature for this review, researchers utilized carefully selected internet search engines, including PubMed, Embase, CINAHL, SPORTDiscus, and Web of Science, to access information on the connection between physical activity and mental health during the COVID-19 pandemic. Additionally, available sources in the form of books and scientific journals were analyzed, focusing on various studies that have explored this topic to identify the connection between different aspects during the pandemic period.

During the research process, special attention was given to internet search engines as a means of identifying relevant information on the connection between physical activity and mental health during the COVID-19 pandemic. Online search engines have proven to be key tools in finding relevant articles, research, and recommendations stemming from conducted studies on preserving mental health through physical activity during the pandemic period. By synthesizing theoretical concepts with concrete examples from the literature, this review provides a comprehensive insight into the current state and future perspectives on the connection between physical activity and mental health in the specific context of the COVID-19 pandemic. Special emphasis was placed on analyzing conducted research to thoroughly understand the link between these two key aspects, providing relevant insights and guidelines for further research and interventions.

Inclusion criteria for the research were selected to precisely explore the connection between physical activity and mental health during the COVID-19 pandemic. The following criteria were applied in the study selection process:

Inclusion Criteria

- Peer-reviewed research articles: Only research articles that have undergone the peer-review process were included in this analysis, ensuring the reliability and quality of the research.
- Focus on physical activity and mental health: Studies investigating the direct link between physical activity and mental health, especially during the COVID-19 pandemic, were included, regardless of other aspects.
- Availability of full articles: Only studies with available full articles were included in this review, enabling a more thorough insight into the research.

Criteria for exclusion

- Irrelevant interventions: Studies that did not directly investigate the relationship between physical activity and mental health during the COVID-19 pandemic were excluded from the review.
- • Abstracts, conferences, and review articles: Abstracts, conference papers, and review articles were intentionally excluded from the analysis to ensure that the review focused solely on primary research studies.
- • Studies published before 2019: It was decided to exclude studies published before 2019 to focus attention on relevant research reflecting contemporary circumstances and challenges related to the COVID-19 pandemic.

The initial search was focused on predetermined key terms, resulting in an extensive set of literature. Subsequently, a thorough evaluation of titles, abstracts, and overall article content was conducted to assess whether they met the criteria for inclusion in this analysis. Studies that were found to be relevant and met the established criteria were retained for further detailed analysis, while those that did not meet the specified criteria were excluded from the review.

Results

After the initial search in electronic databases, a total of 2,443 potentially relevant research papers were identified. After careful analysis, 2,048 papers were excluded. Of that number, 974 were duplicate papers or did not comply with the defined time period, while 1,074 did not meet the previously defined criteria for inclusion or matched the exclusion criteria. Of the remaining 395 papers, 302 were systematic reviews, which, although useful for providing context to the research, did not fit the scope of analyzing individual studies. After the initial review, 93 studies remained for further detailed analysis. Finally, 15 studies were identified as meeting the criteria for inclusion in this literature analysis (Figure 1). More details about the selected papers is shown in Table 1.

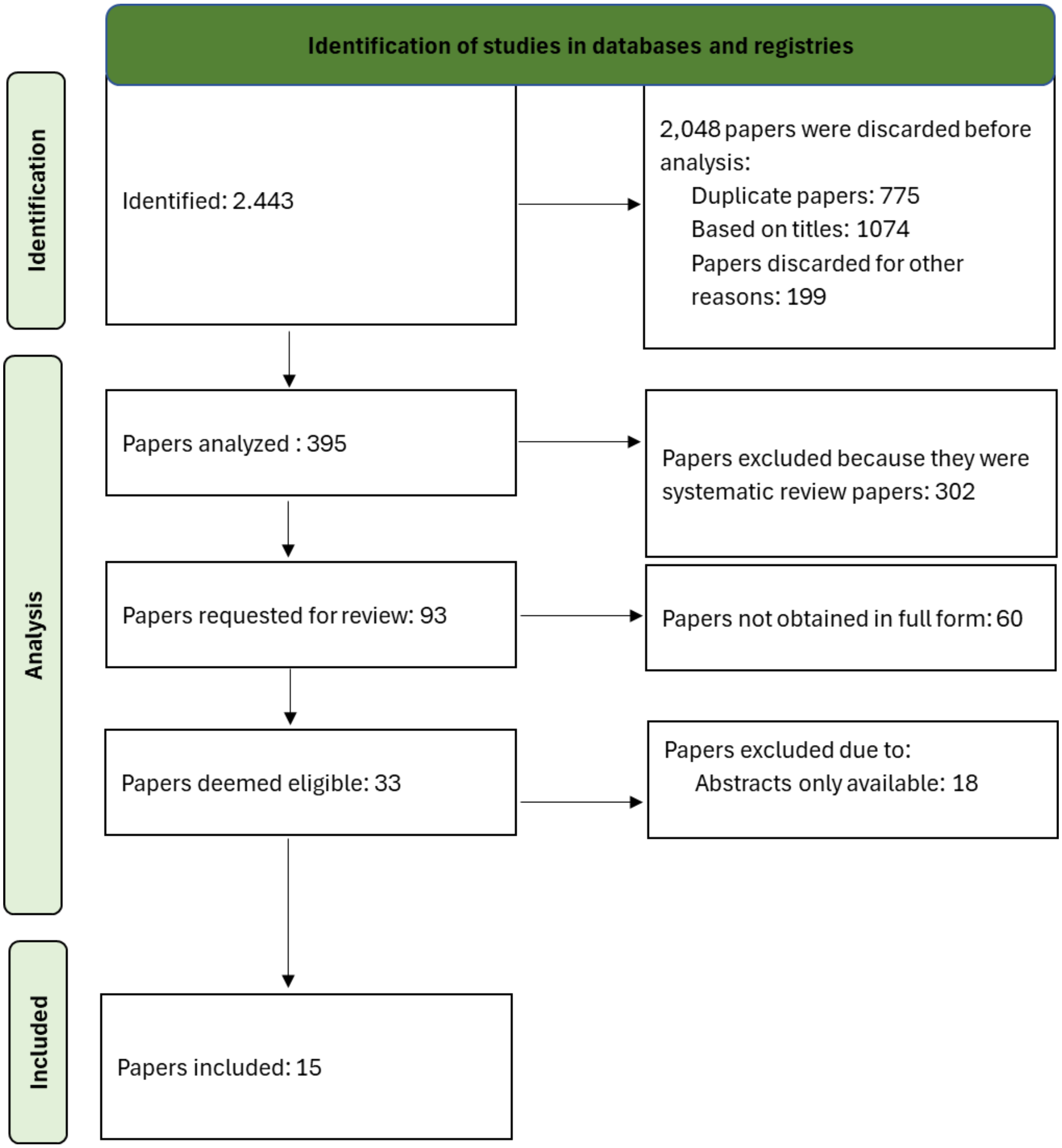

Figure 1. Selection Process for Papers (Origin: Prisma 2020 Flow Diagram for New Systematic Review).

Table 1. Selected studies for analysis.

Reference	Participants N	Participants Sex	Participants Age	Country	Intervention	Variables, Results
Meyer J. et al. (2020)	3.052	M/F	18-75	SAD	APP, S4S, SPS, MAIL, AOU, SS Stata	FA -: DEP+, ANKS+, ST+ FA+: DEP-, ANKS-, ST- SIZ: DEP+, ANKS+, ST+, FA-
Stanton R. et al. (2020)	1491	M/F	50.5 ± 14.9	/	COVID-A; ANK: HZS, DEP, ANKS, ST, FA, FZN, S, P, ALK; AAS; DASS 21; AUDIT-C	FA -:DEP+, ANKS+, ST+, TM+ FA+: DEP-, ANKS-, ST-, P-, ALK- MFA(COVID)= 322,5 ± 36,5 min/w
Fei Q. et al. (2020)	12.107	M/F	18-80	/	IU: FA, ES; VPE, ANOVA, χ^2-T, SKK	FA –: VPE+ (261.3 ± 189.8 min/d), ES- FA +: ES+, VPE-,
Callow D.D. et al. (2020)	1.046	M/F	50 - 95	SAD; CA	OA: DI, ZS, MZ; FA-S; GSD; GSA;	FA -: DEP+, ANKS+, ST+ FA+: DEP-, ANKS-, ST-
Kramerias et al. (2021)	2.541	M/F	42.5 51.2 37.7 40.7	AU, GB, FR, SAD	OA, BU-FA, BU-MZ, UOZ-12, DS, VS, VPE	FA-: MZ-, VS+, VPE+ FA+: MZ+, VS-, VPE- DS-
Faulkner J. et al. (2021)	8.425	M/F	44.5± 14.8	UK, AU, IR, NZ	OA: SSP, IPAQ, IDWHO, DASS 21	FA-: MZ-; DEPR+, ANKS+ FA+: MZ+, DEPR-, ANKS-
Bailey L. et al. (2021)	105	M/F	78.8–80.8	IR	ANK: MZ, FZ, COVID-10-rest., PZU	FA-: MZ-, FZ-,
Kang S. et al. (2021)	4.898	M/F	16 ± 1.3	CN	OA, IPAQ, ES, MWU-T, KW-T	ES(M) > ES(F) FA+: ES+
Yijing X. et al. (2021)	988	M/F	40.9	/	LG, χ^2: FA, MZ, FZ, LP, KP, OP, MZ, RO, RP, HO, RU, FS	FA+ = FS+ = MZ+
Kua Z. et al. (2022)	707	M/F	37.4	SG	MDA: FA, DEP, ANKS, ST, MZ	FA-: MZ-; DEPR+, ANKS+, ST+ FA+: MZ+, DEPR-, ANKS-, ST-
Yufei W., Youqiang L. (2022)	376	M/F	/	CN	ANK: IPAQ, PHQ-9, FCV-19S, GAD-7, SAS-SV, FA, ANKS, DEP	FA-: DEPR+, ANKS+, ST+, SAS-SV+, FCV-19S+ FA+: DEPR-, ANKS-, ST-, ES+, SAS-SV-, FCV-19S-
Andersen J.A. (2022)	754	M/F	47.4 ± 16.3	SAD	MMR: MZ, FA	FA-: MZ- FA+: MZ+
Petersen C.B. et al. (2023)	2.280	M/F	26 ± 5.8	DK	OA: FA, MZ, SEF	FA+: ST+,DEP-, ANKS-,
Maharaja et al. (2023)	308	M/F	42.2	ID	ANCOVA: MZ, MCS, SF-12	FA+: SP+,DEP- FA-: SP-, DEP+
Wut T.M. et al. (2023)	109	M/F	18-65	CN	IU, PS, KOFA, SP, DEP, ANKS, MZ; EXCEL	FA+: MZ+
Ambrosio L. et al. (2023)	26	M/F	38-79	UK	VIDEO-INT., EXCEL, TA.	MOT+, RV+ = FS + MOT-, RV- = FS – FA-: TM+, ES-, MZ- FA+= SI+

Table legend: AAS - Active Australia Survey; **ALK** - Alcohol consumption; **ANK** – Survey; **ANKS** – Anxiety; **ANCOVA** - Analysis of Covariance; **ANOVA** - Analysis of Variance; **APP** - Analysis of cross-sectional data**; AUDIT-C** - Alcohol Use Disorders Identification Test; **AU** – Australia; **BU** - Brunel questionnaire; **CA** – Canada; **COVID-A** - COVID-19 Survey; **COVID-10-rest**. - Attitudes towards COVID-19 restrictions; **CN** – China; **D** – diverse; **DASS 21** - Depression, Anxiety and Stress Scale with 21 items; **DEP** – Depression; **DK** – Denmark; **DS** - daily step count; **ES** - emotional state; **FA** - physical activity; **FA-S** - Physical Activity Scale; **F** – Female; **FCV-19S** - Fear of COVID-19 Scale; **FR** – France; **FS** - physical condition; **FZ** - physical health; **FZN** - physical health habits; **GAD-7** - Generalized Anxiety Disorder Scale; **GB** - Great Britain; **GSA** - Geriatric Anxiety Scale; **GSD** - Geriatric Depression Scale; **HO** - work from home; **HZS** - chronic health conditions; **ID** – Indonesia; **IDWHO** - World Health Organization Well-being Index; **IND** – disability; **IPAQ** - International Physical Activity Questionnaire; **IR** – Ireland; **IU** - internet questionnaire; **KOFA** - amount of physical activity; **KP** - categorical questions; **KW-T** - Kruskal-Wallis test; **LP** - Likert questions; **M** – Male; **MAIL** - email address; **MDA** - multidomain survey; **MCS** - mental component summary; **min/d** - minutes per day; min/w - minutes per week; **MOT** – motivation; **MMR** - multivariate regression models**; MWU-T** - Mann-Whitney U-Test; **MZ** - mental health; **NZ** - New Zealand; **OA** - online survey; **OP** - open-ended questions; **P** – smoking; **PHQ-9** - Patient Health Questionnaire-9; **PMZ** - positive mental health; **PZU** - access to health services; **RO** - work environment; RP – workspace; **RU** - work performance; **RV** - exercise resources; **S** – sleep; **SAD** - United States of America**; SAS-SV** - Smartphone Addiction Scale; **SDG** - social distancing guidelines; **SEF** - Socioeconomic factors; **SF-12** - 12-item Short Form Health Survey; **SG** – Singapore; **SI** - social interaction; **SIZ** - self-isolation; **SKK** - Spearman's rank correlation coefficient; **SP** - self-confidence; **SPS** - perceived stress scale; **SSP** - Stages of Change Scale**; SS-Stata** - Stata Statistical Software; **S4S** - 4-item scale; **T** – test; **TA** - thematic analysis; **TM** - body mass; **UOZ-12** - 12-item health questionnaire; **VIDEO-INT** - video interviews; **VPE** - screen time; **VS** - sitting time; χ^2 - Chi-square test; **Z** – health; **ZS** - health status.

Discussion

Analyzing the available data, significant variability in the number of participants is observed, ranging from a minimum of 26 to a maximum of 12,107 participants. However, variations in sample size are a consequence of research design and all studies meet the criteria for reliable statistical inference. Regarding the age structure of participants, the range varies from 16 to 95 years. The gender distribution of data shows the presence of both genders in the studies, suggesting that both men and women are included in the analyses. These results indicate a wide range of participants involved in the studies, highlighting the need for diverse approaches to studying the effects of physical activity on different demographic groups and pandemic-related contexts. Taking into account the differences in the place of residence, it could be said that the processed studies refer to a wide global population, but also that children were not the subject of research. Research encompassing diverse populations and different measures of physical activity as well as mental and physical health during the COVID-19 pandemic provides deep insights into the impact of this global health event on the physical and mental health of people worldwide.

Meyer et al. (2020) investigated the effects of public health guidelines on levels of physical activity, sedentary behavior, and mental health. Their results indicate a significant reduction in physical activity among those who were previously active, while among previously inactive participants, physical activity remained largely unchanged. Additionally, increased screen time and non-adherence to physical activity guidelines were associated with depression, loneliness, and stress. This study emphasizes the importance of maintaining and enhancing physical activity while limiting screen time to mitigate the negative effects on mental health during the social changes brought about by the pandemic.

Stanton et al. (2020) provided similar findings, highlighting the significant association between changes in physical activity and mental health. Their results show that higher levels of physical activity are associated with reduced symptoms of depression and anxiety, while changes in behavior are associated with increased stress and anxiety. This underscores the importance of promoting physical activity as a means of preserving mental health during the pandemic.

Fei et al. (2020) highlight the concerning prevalence of insufficient physical activity and prolonged screen time during the COVID-19 pandemic. Their findings indicate the need for targeted interventions to promote healthier lifestyle routines, especially among vulnerable groups such as women, young adults, and residents of remote regions.

Callow et al. (2020) investigated the impact of current social distancing guidelines on the mental health of older adults. Their results show that higher levels of physical activity are associated with reduced symptoms resembling depression in older adults. This emphasizes the importance of maintaining physical activity as a means of preserving mental health, especially among the older population who may experience greater stress during isolation.

As a contribution to this context, Faulkner et al. (2021) examined the impact of initial restrictions on physical activity habits in four different countries. Their findings indicate variations in the impact of restrictions on physical activity habits depending on age and gender. This underscores the need for tailored public health interventions targeting specific population groups.

In the study by Kua et al. (2022), an analysis of the relationship between physical activity and mental health during the pandemic was conducted. Their findings show that higher levels of physical activity are associated with lower incidence of depressive symptoms and greater resilience to stress. This research confirms the importance of maintaining regular physical activity as a means of preserving mental health, especially during periods of increased stress and isolation.

Swimming is a natural form of physical activity that has a very positive impact on the human body and organism, enabling significant preventive, corrective, and therapeutic results (Trivun M., Tošić J., Marković V., 2013.). Not only does it positively affect the body, but swimming and diving can also have a beneficial effect on mental health, especially during the COVID-19 pandemic as shown in the study by Maharaj et al. (2023). This study highlighted the significant benefits of swimming in the sea or diving with a mask and snorkel in tropical coastal blue spaces during the COVID-19 pandemic. It was found that individuals who regularly practice swimming or diving showed better mental well-being compared to those who did not participate in this activity. This study clearly indicates a positive correlation between mental health and activities in tropical coastal blue spaces. Additionally, a connection between human health and nature was discovered, emphasizing the importance of access to these natural resources for maintaining mental health. These findings highlight that swimming in natural waters can be an invaluable resource for maintaining mental well-being, while also emphasizing the need to preserve and promote access to these environments, especially for the local population.

The study by Wut et al. (2023) showed that even low to moderate levels of physical activity are positively associated with perceived self-confidence and mental state, while moderate levels of physical activity influenced the improvement of symptoms related to depression and anxiety. These findings underscore the importance and effects of physical activity on mental health, especially among working adults.

Ambrosio et al. (2023) conducted a qualitative study to explore the impact of lockdown during the COVID-19 pandemic on physical activity among people living with chronic conditions in the United Kingdom. Their findings highlight the importance of tailored support for physical activity to preserve the health of this population, especially considering challenges such as loss of social interaction and fear of infection. This study provides useful insights into how people with chronic conditions manage their health during the pandemic, emphasizing the need for adequate support strategies and interventions.

Overall, results of the studies are consistent in many ways. The reduced level of physical activity was accompanied by negative phenomena such as increasing in the body mass (Ambrosio et al., 2023; Stanton et al., 2020), increased smartphone addiction (Yufei, & Youqiang, 2022), more time spent in front of the screen (Fei et al., 2020; Kramerias et al., 2021), more siting time (Kramerias et al., 2021), increased Fear of COVID (Yufei, & Youqiang, 2022), and less self-confidence (Maharaja et al. 2023). On the other side a higher level of physical activity was accompanied by positive phenomena such as reduction of alcohol and tobacco consumption (Stanton et al., 2020), less smartphone addiction (Yufei, & Youqiang, 2022), less time spent in front of the screen (Fei et al., 2020; Kramerias et al., 2021), less siting time (Kramerias et al., 2021), and more self-confidence (Maharaja et al. 2023). It is important to note that a higher level of physical activity was associated with higher level of Social Interaction (Ambrosio et al., 2023), while a lower level of physical activity was associated with self-isolation (Meyer et al., 2020). Therefore, it is not surprising that the most consistent obtained findings characteristic for almost all the processed studies are that higher level of physical activity has been shown to be associated with a reduction in depression (Callow et al., 2020; Faulkner et al., 2021, Kua et al., 2022; Maharaja et al. 2023; Meyer et al., 2020; Petersen et al., 2023; Stanton et al. 2020; Yufei, & Youqiang, 2022) and anxiety (Callow et al., 2020; Faulkner et al., 2021, Kua et al., 2022; Meyer et al., 2020; Petersen et al., 2023; Stanton et al. 2020; Yufei, & Youqiang, 2022) while a reduced level of physical activity had the opposite effect. All of this resulted in observations that a higher level of emotional stability (Ambrosio et al., 2023; Fei et al., 2020; Kang et al., 2021; Yufei, & Youqiang, 2022) and overall mental (Ambrosio et al., 2023; Andersen, 2022; Bailey et al. 2021; Faulkner et al., 2021; Kramerias et al., 2021; Kua et al., 2022; Yijing et al., 2021; Wut et al., 2023) as well as physical health (Bailey et al. 2021; Yijing et al., 2021) are positively associated with physical activity.

All the studies provide consistent findings on the relationship between physical activity and mental health during COVID-19 pandemic. These findings underscore the importance of promoting physical activity as a means of preserving mental health during periods of social distancing and changes in daily life. Further research and implementation of targeted public health interventions are crucial to supporting population health during the pandemic.

Conclusion

Analysing the combined results of multiple studies focused on the relationship between physical activity and mental health in the context of the COVID-19 pandemic, relevant conclusions emerge. Maintaining adequate levels of physical activity during periods of social distancing and restrictions has proven necessary to prevent negative effects on mental health.

The research results indicate a complex dynamic between levels of physical activity and mental health during pandemic measures. Reducing physical activity, especially during lockdowns, has been associated with increased symptoms of depression, stress, and anxiety. On the other hand, even moderate levels of physical activity have a positive impact on mental health, emphasizing the importance of continuous support for this aspect of healthcare.

Additionally, studies have identified specific population groups that are particularly vulnerable to the negative consequences of insufficient physical activity, such as people with chronic conditions or students. Therefore, tailored interventions and support for these groups are crucial for preserving their mental health.

In conclusion, the findings of these studies emphasize the necessity of a comprehensive approach to promoting physical activity for the protection of mental health, not only in extraordinary situations such as pandemics but also in everyday life. It is important to understand that physical activity is more than just disease prevention or maintaining physical fitness; it plays a crucial role in supporting emotional well-being and psychological resilience. Furthermore, further research is needed to better understand the mechanisms behind the relationship between physical activity and mental health, especially in the context of global health challenges. The development of targeted public health strategies, which encompass different population groups and adapt to their specific needs, is a key step towards creating societies that support healthy lifestyles.

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Gender Representation in Management and Coaching Roles in Sports: A Case Study of the Banja Luka Region

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Abstract

This study investigates gender representation in management and coaching roles within sports organizations in the Banja Luka region, Bosnia and Herzegovina. The research aims to provide a detailed insight into the extent of women's participation in decision-making roles and sports activities, revealing existing inequalities. A structured online questionnaire was distributed to 54 sports organizations from eight different types of sports to assess gender distribution in managerial, executive, and coaching roles. The results indicate that men overwhelmingly dominate management leadership positions, with 96.29% of managerial roles occupied by men and 62.9% of organizations having no women in management leadership. Similarly, 52.8% of the clubs do not employ any female coaches. Only 11.1% of organizations reported having policies addressing gender equality, reflecting the absence of formal mechanisms to address these disparities. The findings emphasize persistent barriers, including stereotypes and organizational culture, that hinder the inclusion of women in leadership and coaching roles. This study highlights the need for targeted interventions, including policy changes and educational efforts, to promote gender equality in sports organizations in the region.

Keywords: Gender Equality, Sports Management, Coaching, Sports Organizations, Gender Imbalance

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Introduction

Gender equality is an issue that requires an understanding that gender is a social category shaped and developed in various social contexts such as culture, tradition, science, and education. The assumption is that the biological differences between women and men, or sex, result in differing gender roles, and therefore they should be valued and treated differently (Antonijević & Gavrić, 2021). For over thirty years, gender equality has gradually been taking a clearer shape through international, regional, and national legislative activities. Countries have been encouraged to adopt laws, strategic documents, and implement measures that contribute to achieving equal opportunity policies and gender equality. There has been an ongoing work to change and improve the status of women through specific norms (Walby, 2011). However, research on the slow progression of women within existing hierarchies in organizations and institutions to higher and better-paid managerial positions has concluded that gendering organizations is also necessary (Antonijević & Gavrić, 2021). Symbolic representations (Gherardi, 1995), stereotypes (Heilman, 2012), and prejudices (Eagly & Harau, 2012) regarding what jobs are ideal for women versus men, particularly in high-level managerial positions, also contribute to the maintenance of gender inequalities within organizations (Acker, 2006).

Despite a gradual increase in the number of women in sports over the past few years (Banek, 2020), women are still underrepresented in decision-making bodies in sports institutions at local, national, European, and global levels (Burton & Leberman, 2017; Evans & Pfister, 2021; Murray, 2022). The state of inequality is justified by various factors, often referring to a phenomenon recognized in science as the 'glass ceiling. (' Powell & Butterfield, 1994; Ryan & Haslam, 2005) This concept refers to the barriers (prejudices, discrimination, and stereotypes) faced by women trying to reach or who aspire to higher management positions in corporations, government, and education (Ružić & Perušić, 2014; Zang & Basha, 2023). It is no secret that men predominantly lead sports organizations worldwide (Burton, 2015; 2019), but it is also a fact that women lack opportunities for managerial positions. European society is aware that there are no quick and easy solutions to this problem, but certain efforts and initiatives are being recognized to raise awareness about the importance of gender equality and to create a system in which women will have equal opportunities to be elected to management positions as men (Vaquero-Cristóbal et al., 2024). An increasing number of sports federations in Europe, as well as globally (IOC, UEFA, EHF, UWW-Europe, ETU, ESC) have supported gender quotas through rules and demonstrated their commitment to gender equality and promoting equal access to opportunities for both genders (according to the European Institute for Gender Equality - EIGE, 2015). The trend of promoting women in sports continued with the initiative of the International Football Federation (FIFA) in 2016 called the "Women in Football Leadership Program." This program was created to help women develop their skills and knowledge to become leaders in football. As such, it provides support to women in various countries around the world and helps create a network of women working in football (Filipović et al., 2024).

There is little data and research on the status of the underrepresentation of women in the management structures of sports organizations in the region, particularly in Bosnia and Herzegovina. What is known is that there are solid legal frameworks that support equal rights for men and women, as well as institutional mechanisms for monitoring gender equality. However, the actual capacity, functioning, and impact of these mechanisms vary or are almost not applied (Popović, 2024). According to data from the Agency for Statistics of Bosnia and Herzegovina published in the report "Women and Men in Bosnia and Herzegovina" (2020) regarding the share of women in the management structures of the ten most financed Olympic sports in Bosnia and Herzegovina: taekwondo, cycling, judo, athletics, tennis, boxing, basketball, ice hockey, skating, and volleyball, there were only 5.6% women. In Bosnia and Herzegovina, no woman was the president of the management board of a sports federation in 2020. Out of 17 deputy chairs of the management board, there was only one woman. Compared to the European Union and the status of women there, the data is more than disappointing. All this prompts us to reflect and provokes a logical question: if the situation is such at the state level, what is it like at lower levels, at the levels of entities and local communities?

This research addresses precisely this issue and raises the question of gender inequality in sport organizations in the Banja Luka region focusing on management and coaching roles. Specifically, it seeks to assess the representation and participation of women in decision-making structures and operational functions, identifying the barriers that hinder their inclusion. The study aims to provide evidence-based insights into the current state of gender balance, highlight the systemic challenges women face, and explore whether sports organizations have implemented policies to promote gender equality. Ultimately, the research intends to raise awareness about the need for greater inclusion of women in management positions in sport organizations, contributing to the development of strategies and initiatives that foster equality and break down existing stereotypes and institutional barriers.

Methods

Design and participants

This research employed a quantitative, descriptive cross-sectional design to investigate the gender representation in managerial and coaching roles within sports organizations in the Banja Luka region. A structured online questionnaire was developed to collect data on the gender structure of sports organizations, focusing on management and coaching positions. The sample consisted of 54 active sports organizations from 8 different type of sports (athletics, boxing, football, karate, basketball, volleyball, swimming, and handball). These organizations operate within the broader Banja Luka area and include individual and team sports. Their gender structure is shown in Figure 1.

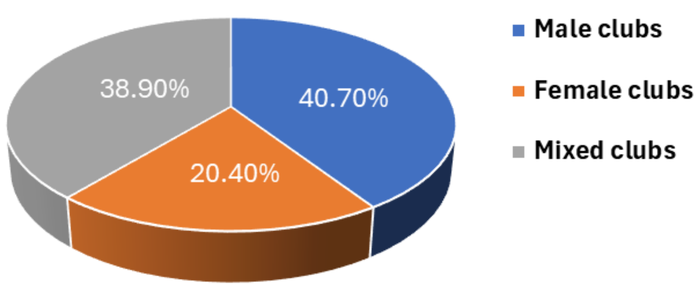

Figure 1. Percentage distribution by club type (individual and team sports).

Variables and data collection

The questionnaire focused on the following gender representation indicators: quantitative data on gender distribution in management and organizational structures (defined by presence and number of women in executive board positions and number of male and female managers/directors) and gender distribution in coaching roles (defined by number of male and female head and assistant coaches). To gain deeper insight into gender distribution, the questionnaire also investigated whether the organizations have established rulebooks or formal procedures promoting gender equality.

The data was collected through a structured online questionnaire. The questionnaire included both closed-ended questions about gender distribution and open-ended questions to explore gender equality policies within the organizations.

Statistical analyses

Data were analyzed using descriptive statistics to determine the frequencies and percentages of men and women in various management roles. The results were compared across different types of sports and club structures (male, female, mixed). Variables such as the number of women and man on executive boards, in managerial roles, and in coaching positions were summarized and visualized using graphs for comparative analysis. The statistical analysis focused on identifying gender imbalances in management and coaching roles, providing insights into the potential barriers women face within sports organizations.

Results

A total of 54 responses were collected from sports organizations (Figure 2) across eight different types of sports (athletics, boxing, football, karate, basketball, volleyball, swimming, and handball) active in the broader Banja Luka area. The highest number (N=17) of responding clubs were from the football federation, followed by the basketball federation (N=12), karate federation (N=8), and volleyball federation (N=7).

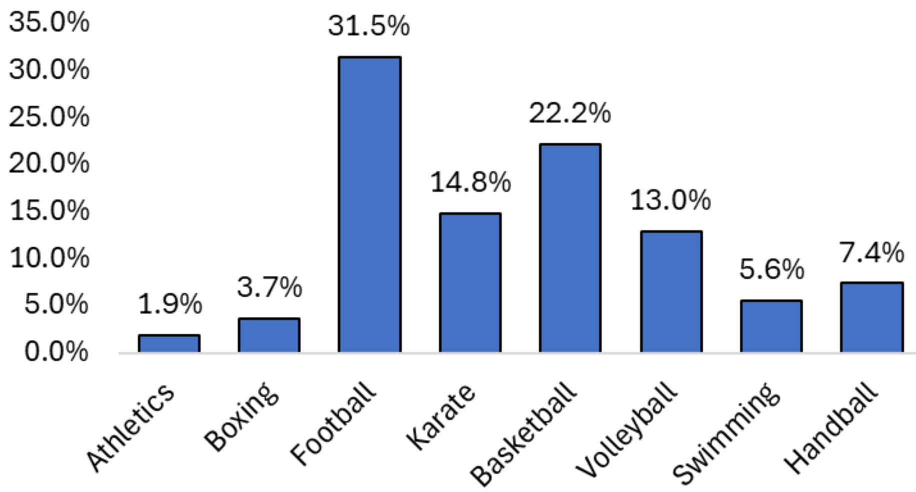

Figure 2. Number of organizations by sport disciplines.

Of the total number of clubs (18) with women in managerial positions (one or two), 10 are mixed clubs, 6 are female clubs, and only 2 are male clubs (Figure 3). The role of club secretary is held by a man in 74.1% of the surveyed sports organizations, while in 25.9% of them, the position is held by a woman.

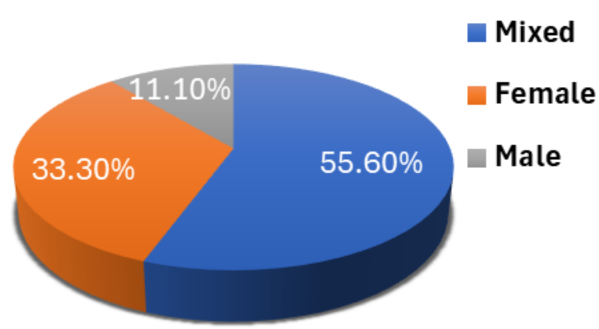

Figure 3. Percentage of clubs with women in management positions - by type of club.

In management positions (director/manager/club leader) in most surveyed clubs (96.29%) there are men, and in 62.9% of clubs, not a single woman holds one of the managerial roles. Only a quarter (25.92%) of clubs have just one woman in a managerial position. When it comes to gender representation in the management bodies of clubs, of the total 54 surveyed sports clubs, the highest number (N=23) has no women as members of the Management Board (UO), while 17 have only one woman as a member of the UO. One organization does not have a UO but only an assembly. When comparing the data with the number of male members of the UO, there is a significantly higher representation of men compared to women. For example, 25 sports clubs have more than four male members on the UO, while only 1 organizations have more than four female members on the UO (Figure 4).

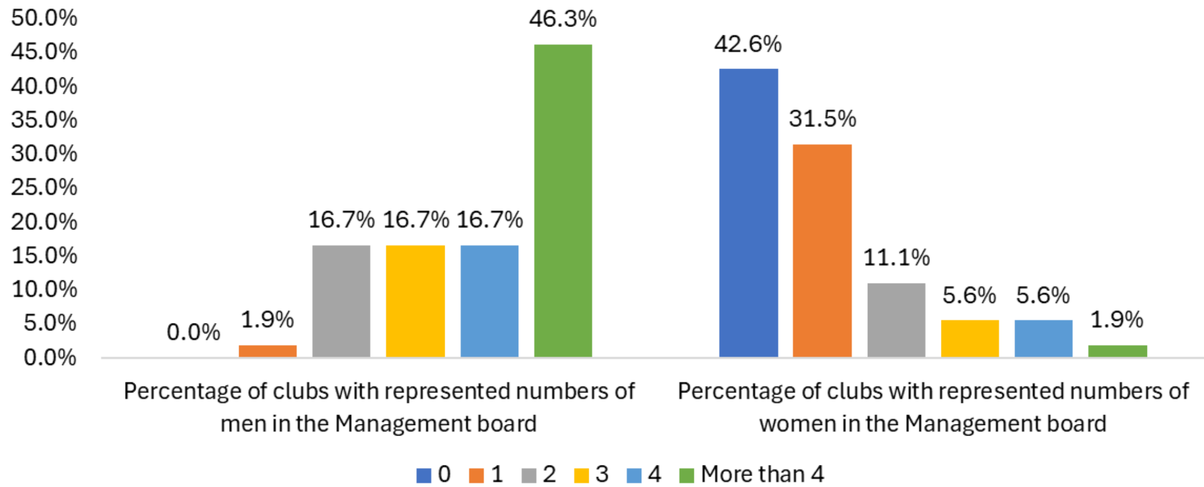

Figure 4. Percentage of clubs with represented numbers of men and women in the Management board.

Regarding the engagement of coaches in the club, one organization (association) does not have this function, so among the total of 53 sports organizations, 28 do not have any women serving as coaches in the club. Within that number, 60.7% are male clubs, 28.6% are mixed clubs, and 10.7% are female clubs. Half of that percentage consists of football clubs (both male and mixed, as well as female), while karate (mixed) and basketball (both female and male) clubs each account for 14.28%, and handball (male), volleyball (both male and female), and boxing (mixed) clubs each account for 7.1%. An overview of the number of sports organizations that have a certain number of women or men engaged in coaching roles is provided in Figure 5.

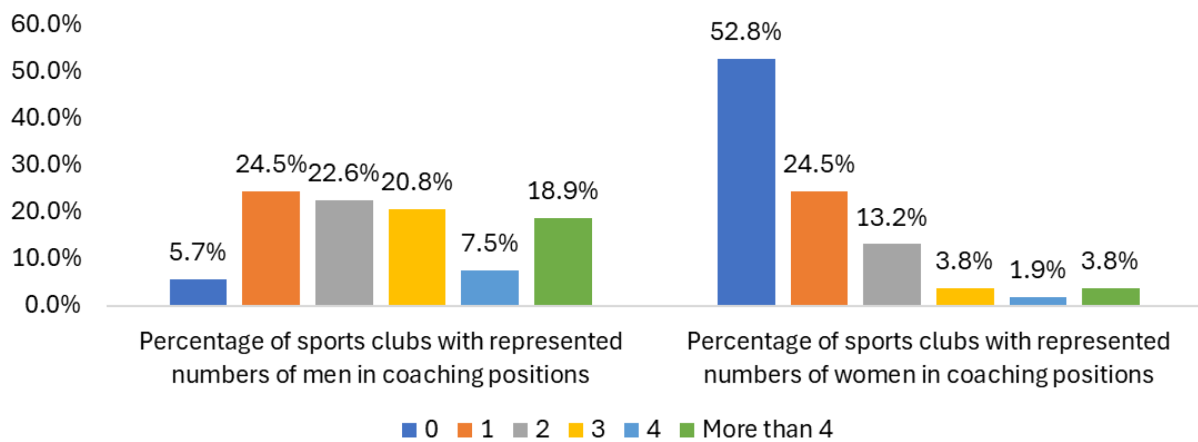

Figure 5. Percentage of sports clubs with represented numbers of men and women in coaching positions.

Out of a total of 22 sports organizations that reported the number of head and assistant coaches and have competitors in the top competition category, 12 (54.5%) have only male head and assistant coaches. Among these 12, there are 7 mixed clubs, 3 female clubs, and 2 male clubs. Additionally, within the structure of these

12 clubs, there are 3 karate clubs, 2 boxing, football, and volleyball clubs, and 1 basketball and handball club each. One sports organization, a mixed karate club, has only female head and assistant coaches. Out of 22 sports organizations, 9 (40.9%) have both male and female head and assistant coaches. Within the structure of these 9 clubs, 6 are mixed clubs and 3 are female clubs. Figure 6 shows the gender representation of head and assistant coaches in the aforementioned nine clubs, indicating that either the percentage of male and female head and assistant coaches is equal or that there is a higher percentage of females in the overall gender structure.

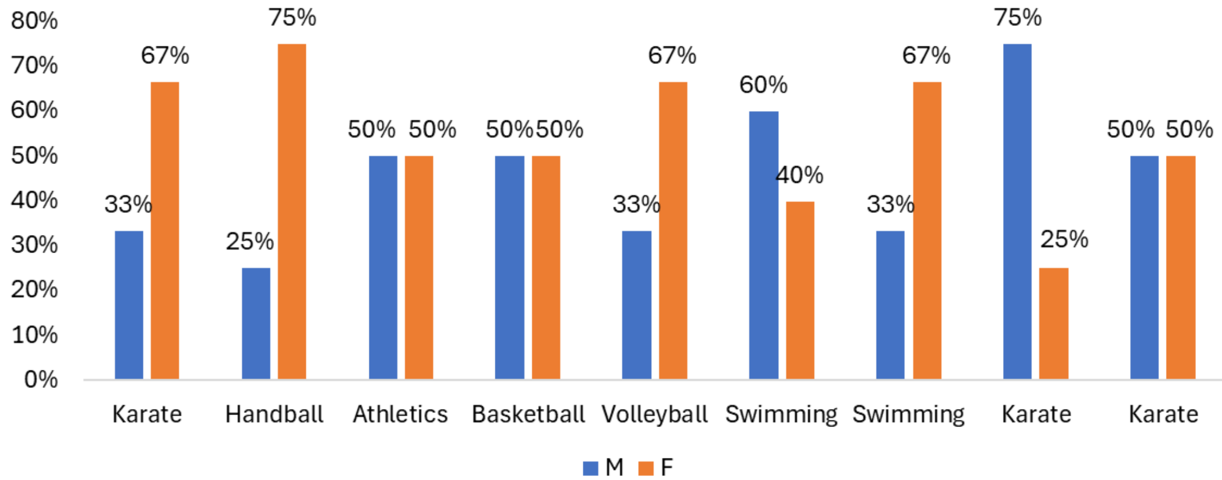

Figure 6. Percentage of sports clubs with represented numbers of men and women in coaching positions.

A survey examining specific policies and regulations related to gender equality within sports organizations revealed that 88.9% of the respondents do not have any formal acts addressing this issue, while only 11.1% do. Among those with policies, most reference their club statutes, and notably, one organizational men's football club has established a separate "Act on Racial, National, and Gender Equality."

The organizations that lack separate acts or rules related to gender equality provided several reasons for this absence. These include a lack of female representation in football, adherence to existing "Sports Law," unawareness of the necessity for such policies, the absence of a legal obligation to implement them, a predominant focus on men's football, and prevailing cultural values. Additionally, some organizations believe that their operational structures do not necessitate a separate act, asserting that gender equality is inherently supported within their existing practices.

Discussion

The findings of this study highlight persistent gender inequalities in sports organizations within the Banja Luka region, particularly in management and coaching roles. Despite legislative frameworks supporting gender equality, 40.7% of surveyed organizations were male-only clubs, 20.4% female-only, and 38.9% mixed clubs. This result aligns with previous studies showing the underrepresentation of women in sports management worldwide and indicating that gender inequality in sports governance remains a global challenge (Burton, 2019; Evans & Pfister, 2021).

A significant gender imbalance was observed in executive and managerial positions, reinforcing the notion that sports management is still dominated by men. In 96.29% of the surveyed clubs, men hold top managerial roles, and no women occupy managerial positions in 62.9% of these organizations. Only 25.92% of clubs have one woman in a leadership role, emphasizing how exclusion remains entrenched. These results correspond with findings from studies across other European countries, such as Norway and Sweden, where men outnumber women in top sports management positions by 4:1, despite long-standing gender equality policies

(Stronach & Adair, 2010). In countries such as the UK, Murray (2022) found that women held only 30% of executive positions in sports governing bodies, mirroring the underrepresentation observed in Banja Luka's sports organizations. Similarly, in France and Germany, female managers comprise less than 20% of top positions in sports (Pape, 2020). Sports are seen as a traditionally male-dominated field, and progress toward gender equality is hindered by social prejudices (Fink, 2015) and established patriarchal cultural norms (Scraton & Flintoff, 2002). Several studies, such as Coakley (2009), Plaza et al. (2017), and Planinić & Ljubičić (2020), support this viewpoint. Bertoluci & Barišić (2020) highlight 'small movements' away from established norms toward more modern perspectives. Nevertheless, substantial and consistent support for such change remains absent, with efforts largely limited to symbolic gestures.

This imbalance highlights that structural barriers and stereotypes still discourage women from pursuing or maintaining management roles in sports (Acker, 2006). Stereotypes that portray management positions as a masculine domain continue to reinforce this inequality (Eagly & Carli, 2007). Additionally, the glass ceiling effect, which refers to invisible barriers preventing women from reaching top positions, has been extensively documented in the context of sports organizations (Zhang & Basha, 2023). These barriers are exacerbated by organizational cultures that tend to promote male managers, leaving women 'on the bench' even when they are qualified to lead (Burton & Leberman, 2017).

The study also reveals significant gender disparities in coaching positions. 52.8% of the surveyed clubs reported no female coaches, reinforcing the narrative that coaching is predominantly male-driven. Even in mixed and female-dominated clubs, men are overrepresented in coaching roles, mirroring trends reported by Burton (2019) and Plaza et al. (2017). The underrepresentation of female coaches was also observed in studies conducted in Australia, where only 17% of professional sports teams had female coaches, despite policies aimed at improving gender diversity (Adriaanse & Schofield, 2014). A similar pattern was identified in Canada, where the percentage of female coaches has plateaued at 30% despite government initiatives aimed at increasing this number (Norman et al., 2019). These studies confirm that the Banja Luka region is not an exception but part of a broader pattern of systemic underrepresentation of women in coaching roles. This lack of diversity is problematic because female coaches serve as role models for young athletes, contributing to their development and performance. It should also be mentioned that female coaches are more prevalent in sports with a high female participation rate (e.g., dance, gymnastics, figure skating, and rhythmic gymnastic), as they primarily work with women, youth, or children competing at the local or regional level.

The absence of formal gender equality measures in many of the surveyed clubs further hinders progress. Only a small percentage of organizations reported having established rulebooks or personnel dedicated to promoting gender equality. This lack of institutional support reflects findings from studies in the US, which emphasize that symbolic policies, without enforcement, fail to address gender disparities in leadership (Acosta & Carpenter, 2014).

The findings suggest that introducing mandatory gender quotas and institutional gender equality plans could help address these disparities, as seen in countries like Spain and Italy, where sports organizations have made modest gains after implementing quota policies (Vaquero-Cristóbal et al., 2024). However, it is essential to recognize that gender quotas alone are insufficient unless accompanied by educational campaigns and cultural shifts to combat stereotypes (Walton et al., 2022). Research suggests that organizational cultures must shift towards inclusive practices, focusing not only on hiring but also on retaining women in management and coaching roles (Ružić & Perušić, 2014).

The small sample size and regional scope, which focused primarily on 54 sports groups in the Banja Luka region, limited the findings' generalizability to other regions or national contexts. Furthermore, the study does not investigate other roles where gender disparities may exist, such as administrative or operational roles within sports organizations. A more comprehensive approach could delve deeper into gender inequalities by investigating not only management and coaching roles but also the impact of organizational culture, recruitment practices, and policy implementation across various functions within sports organizations. Despite the study's limitations, it is important to highlight that this research presents pioneering initiatives in raising awareness of leadership inequalities in sport in the Republic of Srpska.

Conclusion

The general conclusion of the study is that women are underrepresented in management positions within sports clubs in the wider Banja Luka region. It highlights the need for targeted interventions to overcome cultural and structural barriers that prevent women from taking on management and coaching positions. Future initiatives should focus on policy changes, educational efforts, and the development of supportive networks for female managers and coaches. Implementing these measures is crucial for fostering a more equitable and inclusive environment in sports, ultimately benefiting both individuals and organizations. This study provides valuable insights into the structural and cultural barriers that prevent women from achieving equality in sports management and coaching roles. The findings align with global trends, confirming that gender disparities in sports are persistent and require targeted interventions. Future initiatives in the Banja Luka region should focus on implementing gender-sensitive policies, educational efforts, and the development of supportive networks for female leaders and coaches. Active mentorship programs could help accelerate progress toward greater inclusivity. Additionally, long-term monitoring and evaluation mechanisms are essential to ensure that these policies translate into meaningful change.

The importance of achieving gender balance in sports governance cannot be overstated, as diverse management leads to better decision-making and more inclusive environments. Addressing the cultural and institutional barriers highlighted in this study will require concerted efforts from policymakers, sports organizations, and the broader community.

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Conflict of interest: All authors declare that they have no conflict of interest relevant to the content of this article.

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Original article

Initial Study on Normative Data for Hand Grip Strength and Explosive Strength in Lebanese Population

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Abstract

The primary aim of this study is to define the norms as initial standards for handgrip strength for the Lebanese population. The secondary aim is to make a comparative analysis of these values with other available data. The study involved 303 healthy adults (179 males and 124 females) who represented diverse educational and training backgrounds across different regions of Lebanon. Participants' height and weight were assessed. Grip strength was measured for both dominant and non-dominant hand using a standardized handgrip strength protocol. Handgrip strength values were presented as absolute and relative (i.e., normalized to body mass) values. The analysis indicates that the summarized maximal force from both hands (F_{max}_SUM) and summarized rate of force development (RFD_{max}_SUM) in males and females align closely with international findings, within ±1 standard deviation. Compared to international standards, Lebanese handgrip strength values differ by 2.14% for males and 3.32% for females. However, more significant disparities are observed in explosive strength, with differences of 13.44% for males and 22.81% for females. Significant between-sex difference could be observed in F_{max}_SUM (45.35%) and RFD_{max}_SUM (48.75%), with males showing higher values than females.

Keywords: Gender Dimorphism, Muscle Force, Rate of Force Development, Normative Data

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Introduction

Across the epochs of human history, the hand has remained an anatomical phenomenon, essential for executing a diverse range of occupational tasks requiring precise coordination of hand-arm movements (Dogu et al., 2014). These activities, extending from fundamental actions such as dressing and grooming to complex professional duties, underscore the indispensability of the hand in facilitating human pursuits (Dopsaj et al., 2022). Furthermore, hands are regarded as multifaceted organs capable of facilitating intricate and precise interactions with the surrounding environment (Sobinov & Bensmaia, 2021). Hand health provides valuable insights into overall well-being, with vascular, musculoskeletal, and dermatological indicators offering diagnostic clues for various systemic conditions. Thus, the hand can serve as a crucial diagnostic window into the complex relationship between health and disease.

Throughout various activities, hands generate adequate strength by exerting the appropriate muscle force for gripping, a phenomenon referred to as muscle strength. This term is defined as the capacity of an individual muscle or a collective group of muscles to generate force during contraction against an external resistance (Dopsaj et al., 2019). The most frequently investigated mechanical characteristics of isometric muscle strength consist of maximal isometric force (F_{max}) and maximal isometric rate of force development (RFD_{max}). These two parameters can be effectively assessed using the maximal handgrip strength test (HGS), providing valuable insights into an individual's general strength capacity (Dopsaj et al., 2018; Dopsaj et al., 2022).

Also, HGS is a quick and practical method for identifying individuals with muscle weakness or those prone to various health issues like chronic diseases, cognitive decline, extended hospital stays, and mortality (Kocher et al., 2019). It should be noted that HGS is significantly influenced by age, gender, body size, as well as nutritional status, lifestyle, and occupation (Lam et al., 2016). Studies have shown that a weak grip is linked to a higher risk of mortality from cardiovascular disease and cancer, even after considering muscle mass and body mass index (Massy-Westropp et al., 2011). Assessing handgrip strength is a useful way to evaluate muscle function and quality of life, indicating not only hand muscle strength but also associations with strength in other body muscles as an indicator of overall body muscle strength (Miller et al., 1993; Salama et al., 2023). Strong hand grip strength is associated with healthy bone density, leading to suggestions of using it as a screening tool for osteoporosis and sarcopenia (Massy-Westropp et al., 2011; Saraiva et al., 2021).

Generally, the absence of normative handgrip strength data in Lebanon poses a challenge for healthcare providers and fitness professionals in accurately evaluating and guiding individuals. Multiple studies stress the importance of having population-specific normative data for handgrip strength, highlighting the need to tailor such data based on demographic, lifestyle, and ethnic factors (Leyk et al., 2007; Wang et al., 2018; Kocher et al., 2019; Alrashdan et al., 2021; Andraos et al., 2024. Therefore, the primary aim of this study was to define the initial standards for handgrip strength for the Lebanese population filling a gap in existing data for this demographic. The secondary aim is and to compare those norms to those in other countries and to international standards.

Methods

Design and participants

A diverse cohort of 303 healthy adult participants comprising 179 males and 124 females from various training backgrounds and regions across Lebanon were recruited for this study. All participants gave written consent following approval from the Antonine University Ethical Committee under the code 413 reference number 1675-2023, with specific requirements such as being free from limb injuries and hormonal disorders, abstaining from vigorous physical activity 48 hours prior to testing, and fasting for a minimum of 1.5 hours to maintain test validity and reliability. The research was conducted according to the Declaration of Helsinki (Christie, 2000). Basic characteristics of the sample are shown in Table 1.

Table 1. Descriptive data related to body composition characteristics according to gender

Variables	Mean	SD	CV %	SEM	Min	Max
Males						
Age (yrs.)	30.6	14.13	45.48	1.05	18.0	81.0
BH (cm)	176.8	7.2	4.06	0.53	158.0	200.0
BM(Kg)	81.4	14.6	18.02	1.09	53.6	145.3
BMI (kg/m$^{2)}$	25.98	4.04	15.38	0.3	16.9	42.5
BFM (Kg)	16.7	9.4	55.29	0.7	2.8	73.3
SMM (Kg)	34.0	9.2	27.05	0.69	23.52	58.2
PSMM (%)	44.12	6.27	14.31	0.47	24.8	59.9
PBF (%)	20.38	7.92	39.50	0.6	3.3	51.8
Females						
Age (years)	31.2	14.3	46.12	1.28	18.0	73.0
BH (cm)	163.3	6.3	3.86	0.56	149.0	183.0
BM(Kg)	63.8	12.29	19.21	1.1	39.4	113.4
BMI (kg/m$^{2)}$	24.01	4.58	19.16	0.41	16	39.7
BFM (Kg)	21.1	9.9	47.14	0.88	6.6	57.2
SMM (Kg)	20.2	6.0	30.00	0.53	11.0	33.0
PSMM (%)	32.87	6.19	18.78	0.56	20.8	50.0
PBF (%)	32.67	8.82	26.66	0.8	13.6	50.4

Measurement procedures

Anthropometrics

Physical assessments were carried out at the university's Laboratory of the 3S: Sport, Santé, Société (L3S), following standardized procedures. A qualified nutritionist conducted the physical measures, which included weight (BM), height (BH), body mass index (BMI), body fat mass (BFM), skeletal muscle mass (SMM), percentage in body fat mass (PBF), and percentage in skeletal muscle mass (PSMM) (Dopsaj et al., 2020; Rakić et al., 2022; Andraos et al., 2024). For body composition and anthropometric characteristics all measurements were made with bioelectrical impedance analysis (BIA, i30, Mediana, Korea), and a portable digital height scale (Campry, China) was used.

Handgrip strength test

The handgrip isometric test protocol was implemented following standardized procedures and using standardized handgrip device (Sports Medical Solution, Belgrade, Serbia). Subjects were seated upright in a chair, with one arm extended and holding the device, as described in previous literature (Dopsaj et al., 2019; Dopsaj et al., 2022). Previous studies have demonstrated high reliability of this handgrip test, with intraclass correlation coefficients between 0.938 and 0.977 for F_{max} and 0.903 to 0.971 for RFD_{max} (Marković et al., 2018). Prior to the test, participants received verbal instructions and performed two practice measurements with each hand. The test required exerting maximum pressure on the device for at least 2 seconds upon a signal, with verbal encouragement provided. Both dominant and non-dominant handgrip tests were conducted twice in random order, separated by a 1-minute interval of rest. During testing, participants were instructed to keep their arms by their side, with the tested arm slightly abducted from the body. F_{max} and RFD_{max} values were recorded using a laptop computer, with F_{max} representing the maximum muscle force achieved and RFD_{max} calculated as the maximum slope of the force-time curve. The onset of contraction was determined when the force-time curve's first derivative exceeded the baseline by 3% of its maximal value. The strain gauge used for testing was connected to a force reader with a precision of ± 0.1 N, and data were sampled at 500 Hz and filtered before calculating RFD_{max}. Data collection and processing were carried out using a software-hardware system designed for isometric measurements (Sports Medical Solutions Isometrics, ver. 3.4.0).

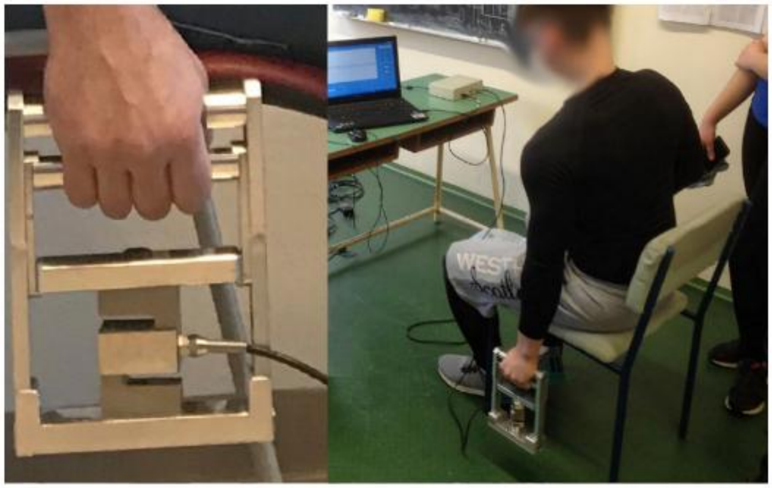

Figure 1. Photo showing the handgrip test position

Handgrip strength test

This study utilized a range of anthropo-morphology and performance variables to comprehensively analyze handgrip strength and explosive strength among the Lebanese population. The variables included age, gender, and several body composition metrics, such as Body Mass Index (BMI), Body Fat Mass (BFM), Skeletal Muscle Mass (SMM), Percent Skeletal Muscle Mass (PSMM), and Percent Body Fat (PBF). Performance variables were - Maximal Force (F_{max}) and Rate of Force Development (RFD_{max}) were recorded to assess the peak force and the speed of force generation during handgrip exercises, respectively, as a performance variables of handgrip strength and explosive strength. Additionally, relative measures such as Relative Force (F_{rel}) and relative Rate of Force Development (RFD_{rel}) were calculated to account for differences in body weight among participants, offering a more standardized comparison of muscular strength.

Statistical analyses

Descriptive statistics, such as the mean (Mean), standard deviation (SD), minimal and maximal measured value (MIN, MAX), coefficient of variation (CV%), the standard error of measurement (SEM) and its percentage relative to the mean (SEM%) were calculated for all variables to assess the precision and reliability of the measurements, and to provide indicators of central tendency and the dispersion of original data. To establish significant ranges for the data under examination, a 95% confidence interval for the mean was determined, including lower and upper bound reference lines. Normative values were derived utilizing two distinct metrological procedures methodologies: the calculation of seven classes' normative standard (7D - Very poor, Poor, Below standards, Standards, Above standards, Excellent and Superior) and the utilization of percentile distribution criteria (2.5, 5, 10, 30, 50, 70, 90, 95, 97.5 percentiles), according to Zatsiorsky (1982). Additionally, a MANOVA (Multivariate Analysis of Variance) was conducted to compare the all explored force (F_{max}_Sum) and rate of force development variables (RFD_{max}_Sum) between male and female participants, as a gender dimorphism data in absolute and relative values. To evaluate Lebanon's alignment with international standards for handgrip parameters related to maximal force (F_{max}_SUM) and rate of force (RFD_{max}_SUM) development across both genders, we compared the mean and standard deviation from previous studies on different populations. Lebanon's values were analyzed for agreement within the range of -1 to +1 standard deviation. Statistical analyses were carried out utilizing the software packages SPSS Win Statistics 26.0 and Excel 2016.

Results

Table 2 summarizes the descriptive results for key handgrip strength parameters by gender. The coefficient of variation (CV%) and standard error of measurement (SEM) indicate the consistency and precision of these measurements for both genders.

The handgrip test outcomes, acquired using a measuring tool, reveal minimal absolute measurement discrepancies. In males, discrepancies for F_{max} and RFD_{max} in both absolute and relative terms were 1.53% and 20.4%, respectively, while for females, the discrepancies were 2.38% and 26.45%.

Table 2. Descriptive statistics

Variables	Mean	SD	CV%	SEM	95% CI lower bound	95% CI upper bound	Min	Max
Males								
F_{max}_SUM (N)	957	180	18.8	1.41	931	984	494	1690
RFD_{max}_SUM (N/s)	5800	1324	22.8	1.71	5605	5996	1638	11457
F_{rel}_SUM (N/kg)	11.92	2.13	17.9	1.33	11.61	12.24	6.93	17.90
RFD_{rel}_SUM (N/s/kg)	72.34	16.08	22.2	1.66	69.97	74.49	22.97	111
Females								
F_{max}_SUM (N)	523	107	20.5	1.84	504	542	254	823
RFD_{max}_SUM (N/s)	2972	914	30.7	2.76	2810	3135	752	5195
F_{rel}_SUM (N/kg)	8.38	1.92	22.9	2.06	8.04	8.73	4.24	14.19
RFD_{rel}_SUM (N/s/kg)	47.61	15.10	31.7	2.85	44.92	50.29	12.55	93.90

Table 3 presents the initial normative data standards for handgrip strength in the Lebanese population, divided by gender and categorized into seven levels ranging from 'Very Poor' to 'Superior.' The classification includes the sum of both hands for absolute and relative values of F_{max} and RFD_{max} for males and females, providing reference values to assess grip strength characteristics in the adult Lebanese population.

Table 3. Handgrip strength initial normative data standards in the Lebanese population by gender

Variables	Very poor	Poor	Below Average	Average	Above Average	Excellent	Superior
Males							
F_{max}_SUM (N)	≤596	597-776	777-866	867-1047	1048-1137	1138-1318	1319≥
RFD_{max}_SUM (N/S)	≤3152	3153-4476	4477-5138	5139-6462	6463-7124	7125-8448	8449≥
F_{rel}_SUM (N/kg)	≤7.65	7.66-9.78	9.79-10.85	10.86-12.99	13.00-14.05	14.06-16.18	16.19≥
RFD_{rel}_SUM (N/kg/s)	≤40.17	40.18-56.25	56.26-64.29	64.30-80.38	80.39-88.42	88.43-104.50	104.51≥
Females							
F_{max}_SUM (N)	≤307	308-415	416-468	469-577	578-630	631-738	739≥
RFD_{max}_SUM (N/s)	≤1143	1144-2057	2058-2514	2515-3429	3430-3886	3887-4800	4801≥
F_{rel}_SUM (N/kg)	≤4.53	4.54-6.45	6.46-7.41	7.42-9.34	9.35-10.30	10.31-12.22	12.23≥
RFD_{rel}_SUM (N/s/kg)	≤17.40	17.41-32.50	32.51-40.05	40.06-55.16	55.17-62.71	62.72-77.81	77.82≥

Table 4 presents handgrip strength percentiles for males and females in the Lebanese population. These percentiles offer a reference for assessing grip and explosive strength in this population.

Table 4. Handgrip strength initial standards percentiles for Lebanese males and females

Percentiles		F_{max}_SUM	RFD_{max}_SUM	F_{rel}_SUM	RFD_{rel} _SUM
Males (n=179)	2.5	661	3310	8.34	38.72
	5	684	3943	8.75	45.99
	10	751	4240	9.20	51.62
	30	869	5137	10.42	64.32
	50	944	5759	11.92	71.31
	70	1031	6400	13.23	80.87
	90	1145	7270	14.73	94.56
	95	1314	8071	15.76	98.06
	97.5	1429	8876	16.21	103.98
Females (n=124)	2.5	291	1311	4.60	18.21
	5	322	1370	4.99	22.34
	10	405	1750	5.53	26.26
	30	469	2550	7.42	39.96
	50	526	2904	8.55	48.76
	70	575	3525	9.35	55.69
	90	678	4187	10.89	67.22
	95	706	4498	11.49	72.31
	97.5	760	4682	11.77	75.17

The results presented in Table 5 indicate significant gender differences in all handgrip strength parameters among the Lebanese population. Males showed higher values for both and relative compared to females (Figure 2). The p-values ($p < 0.001$) confirm that these differences are statistically significant, highlighting the distinct variations in handgrip strength between genders.

Table 5. Gender differences in Handgrip Strength parameters in the Lebanese Population

Dependent Variable	**Males (Mean ± SD)**	**Females (Mean ± SD)**
F_{max}_SUM (N)	957 ± 180	523 ± 107***
RFD_{max}_SUM (N/s)	5800 ± 1324	2972 ± 914***
F_{rel}_SUM (N/kg)	11.92 ± 2.13	8.38 ± 1.92***
RFD_{rel} _SUM (N/kg/s)	72.34 ± 16.08	47.61 ± 15.1***

Note: ***Significant at p < 0.001.

Figures 2-5 show the hand grip strength values across different countries where Lebanon can be compared. Data are shown for F_{max} and RFD_{max} for males and females.

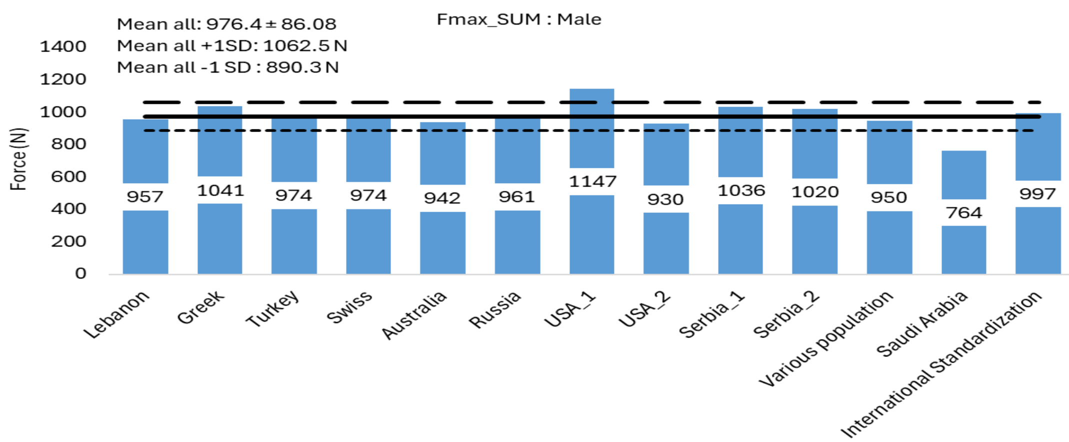

Figure 2. Comparison of current F_{max}_SUM and previously published data for males

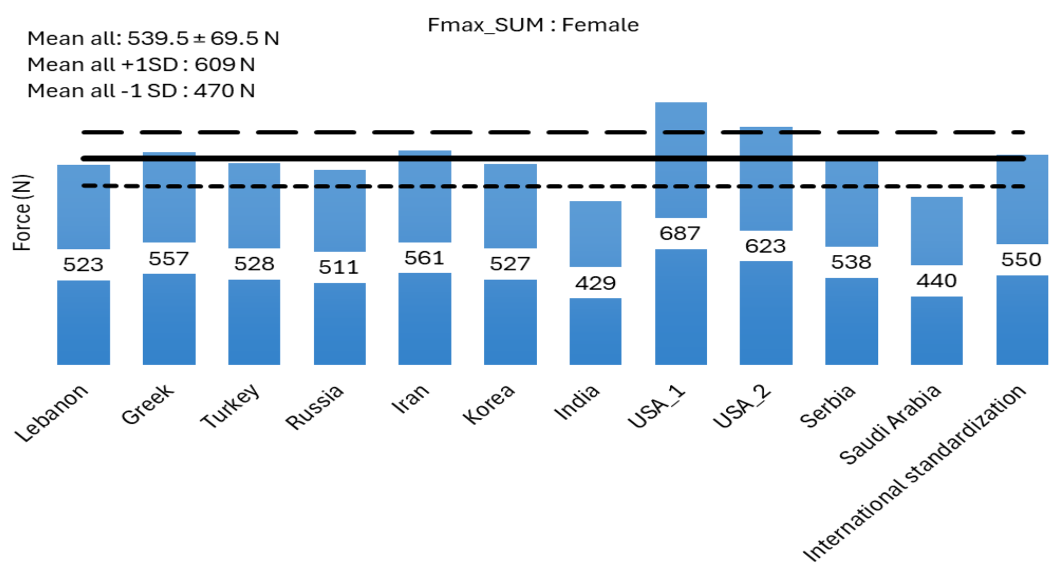

Figure 3. Comparison of current F_{max} _SUM and previously published data for females

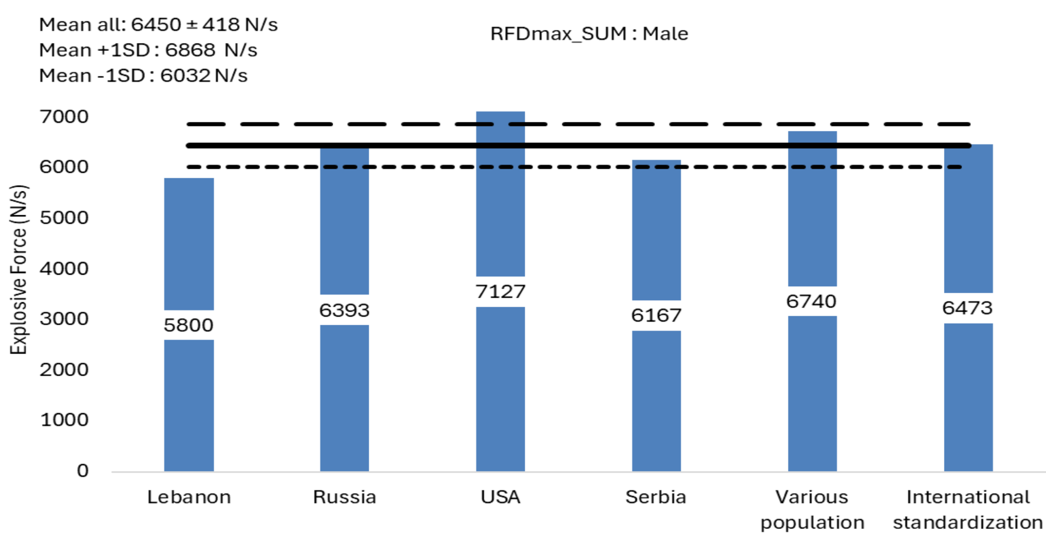

Figure 4. Comparison of current RFD_{max}_SUM and previously published data for males

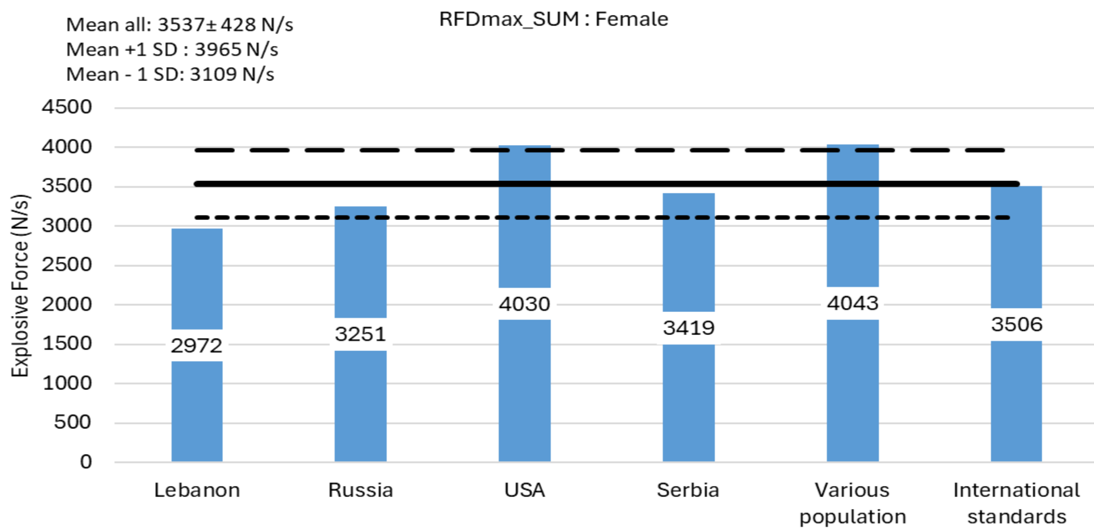

Figure 5. Comparison of current RFD_{max}_SUM and previously published data for females

Discussion

The primary objective of this study is to establish baseline norms for handgrip strength within the Lebanese population, addressing a significant gap in the current data available for this group. Additionally, the study evaluated between-sex differences and evaluated newly defined norms against those from other countries. The descriptive data analysis provided the initial standards for Lebanese population, the between-sex comparison defined the differences between males and females, while the initial standards were compared to international data.

Based on the obtained data, it can be concluded that the values of F_{max}_SUM in males and emales are at the level of 957 ± 180 N, and 523 ± 107 N, while for RFD_{max}_SUM they are at the level of 5800 ± 1324 N/s, and 2972 ± 914 N/s, respectively (Table 2). The relative values showed that Lebanese males and females were able to achieve a total of 11.92 ± 2.13 and 8.38 ± 1.92 hand grip muscular forces per kg of body mass, as well as 72.34 ± 16.08 and 47.61 ± 15.10 N/s/kg hand grip explosive muscle forces per kg of body mass, respectively (Table 2).

The analysis outcomes indicated that the mean values for maximal force are closely aligned with previously reported findings, falling within the range of -1 to +1 standard deviation for both genders. The average handgrip strength in international populations is slightly higher compared to the Lebanese population, with a margin of 1.94% for males and 3.32% for females. Note that the expected between-sex difference in hand grip strength parameters reflected also in comparison of sex-related national data to sex-related international data. However, in terms of the rate of force development, Lebanon did not align with international standards as it was below 1 standard deviation. The difference in the rate of force development between the populations was more significant, with a 10% difference for males and a 15.97% difference for females. The differences in explosive strength observed between the Lebanese population and international counterparts could be attributed to several factors. Ethnic, hormonal and genetic factors play a significant role, as genetic predispositions were reported to influence muscle fiber composition and explosive strength, with variations in muscle fiber types among different ethnic groups partially explaining the differences (Chiu et al., 2020; McGrath et al., 2020; Semenova et al., 2022). Lifestyle and physical activity levels, which vary widely between populations, should also be considered (Hopwood et al., 2023; Domaradzki et al., 2023; Bouchard et al., 1997). In Lebanon, cultural practices, occupational physical demands, and recreational activities might differ from those in other countries, impacting muscle performance. Differences in body composition type, dietary habits and nutritional intake between Lebanese individuals and their international counterparts could contribute to the variance in explosive strength (Ben Mansour et al., 2021; Andraos et al., 2024). Socioeconomic factors could also play a role as these were found to influence physical development and performance, as access to sports facilities, quality of training, and healthcare can vary significantly, impacting opportunities for developing explosive strength (Nieczuja-Dwojacka et al., 2023; Domaradzki et al., 2023).

To further understand these differences, future research should consider several directions. Genetic analysis could investigate genetic markers associated with muscle performance, providing insight into the role of genetic predisposition in explosive strength differences. Collecting comprehensive lifestyle surveys on daily activities, occupational demands, recreational habits, and physical activity levels can correlate these factors with explosive strength metrics. Detailed nutritional assessments can help understand the nutritional influences on muscle performance and identify potential dietary modifications to enhance explosive strength. Implementing and evaluating targeted training programs focused on improving explosive strength in different demographic groups within the Lebanese population and comparing their effectiveness with those used in other countries can offer valuable insights. Exploring the impact of socioeconomic factors on access to training facilities, quality of coaching, and overall physical fitness can help design policies to bridge gaps and promote equitable access to resources for physical development.

A significant limitation of this study is the lack of extensive data on the historical context of the researched populations in Lebanon and other countries, particularly concerning their childhood and adulthood pastimes and daily work activities. These aspects can significantly influence maximal force and rate of force development. To overcome this limitation, future research should adopt a more thorough data collection strategy that includes detailed accounts of physical activity levels, advanced demographics, and work requirements. This data could provide valuable insights into the lifestyle influences on muscular performance, enabling a more nuanced analysis of study outcomes. Moreover, current research on handgrip in Arabic nations is scarce, with only one study conducted in Saudi Arabia. This gap emphasizes the need for further investigation into handgrip dynamics in Arabic countries, considering physical activity patterns, lifestyle choices, and nutritional profiles.

Conclusion

The investigation presents normative data for handgrip strength and explosive strength in the Lebanese population. Handgrip strength outcomes for the Lebanese cohort closely correspond to global standards, showing minimal deviations. However, there is a more noticeable contrast in explosive strength levels between the Lebanese group and international standards, albeit still within acceptable limits. This finding suggests that although Lebanese individuals display similar handgrip strength to their global counterparts, there are noticeable significant differences in explosive strength that necessitate further exploration. Subsequent research should involve a larger sample size to gain a deeper understanding of these distinctions and to verify if the Lebanese populace consistently conforms to global benchmarks in terms of explosive strength. This research establishes a vital reference point for health and performance evaluations in Lebanon. For fitness instructors and trainers, these standards can aid in identifying and nurturing promising athletes by recognizing individuals who meet or surpass the established criteria. Moreover, medical practitioners can utilize this information to evaluate and monitor health hazards, aiming to enhance overall well-being and mitigate risks associated with muscular weakness.

Conflict of interest: All authors declare that they have no conflict of interest relevant to the content of this article.

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