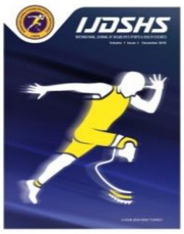

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RESEARCH ARTICLE

Is There a Relationship between Low Back, Hamstring, and Ankle Flexibility with Rowing Performance in Elite Rowers?

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Abstract
The study aimed to evaluate the relationship between low back, hamstring, and ankle flexibility with rowing performance. The study included 26 male rowers (mean age: 16.72±0.73 years). All participants were assessed regarding the flexibility of the low back, hamstring, ankle, and rowing performance by sit and reach (Baltaci et al., 2003), weight-bearing lunge (Powden et al., 2015)., and 2000-m rowing ergometer performance time tests (Mikulić et al., 2009), respectively. No correlation was found between sit and reach and 2000-m rowing ergometer performance time test results. However, a negative correlation was found between ankle flexibility and 2000-m rowing ergometer performance time test results (r= -0.39; p <0.05). Additionally, 2000-m rowing ergometer performance time test result was negatively correlated with anthropometric variables and the training frequency of rowers in a week. The stepwise multiple regression analysis results indicated that only training frequency had a significant impact on the outcome variable. Conversely, weight, height, and ankle flexibility were insignificant predictors in the analysis (R2 = .492; R = .39, p<0.05). The training frequency plays a crucial role in influencing the outcome variable. Other factors, such as weight, height, and ankle flexibility, did not demonstrate significant associations. However, it is essential to note that the regression model only takes into account a medium level of variance. Future studies may examine the potential impact of other risk factors.

Keywords
Flexibility, Performance, Rowers, Sports, Male

INTRODUCTION

Rowing is a famous Olympic sport considered one of the most compelling endurance sports. A typical rowing competition hold out 2000, about 5.5–7.0 minutes, depending on the weather and boat type (Mäestu & Jürimäe, 2005). Rowing stroke comprises two main phases, including the drive, where the oar is propelled backwards by extending the legs and moving the upper body backwards, and the recovery phase, where the body returns to its initial position in preparation for the next drive. The rowing stroke, consisting of the recovery and drive phases, is repeated 200–250 times in a 2000-meter race (Hosea & Hannafin, 2012). Precise posture is not only the tremendous sport of rowing to improve the performance but also to avoid injury. Settling into a seated position, the rowers learn to put equal weight on the sit bones, thus keeping their balance while rowing. The rowers, then, tie their feet in the foot straps that forms a solid connection between their feet and the foot stretcher of the rowing machines. Catching requires a straight back and upright torso to maintain the core strength that will provide the spine support. Leaning forward from the hips is also needed to create the proper angle. With arms fully extended, the rower is ready to enter the drive phase that starts from a forceful leg push. With extending of the legs, there is a controlled lean back which brings the handle down to lower chest or upper abdomen. In the recovery, the detail of releasing the arms, bending the knees smoothly, and pivoting at the hip is particularly crafted to return to the catch

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position. As to rowers a neutral head position and rhythmic breathing are supposed to add to the subtle postural considerations contributing not only to the efficiency and performance, but also to the sturdiness of their rowing careers by lowering the risk of injuries (Secher & Volianitis, 2009; Soper & Hume, 2004;Rumball et al., 2005; Ogurkowska et al., 2015; Thompson & Wolf, 2016). The complete manifestation of rowers' performance largely depends on the synchronicity and efficacy of specific muscle groups used. The quadriceps, hamstrings, and gastrocnemius muscles constitute the powerhouse trio that provides the required power to move the boat forward. Meanwhile, the core muscles, including abdominals, obliques, and the lower back, act as true protectors of posture. They remain stable and resilient to the forces at work. The posterior muscles, such as the latissimus dorsi and rhomboids, which direct the paddle during the crucial phase of disengagement and contribute to maintain a desirable lean back, provide power as well as elegance to the stroke. The precision is advanced through the activity of shoulder and arm muscles producing controlled and accurate movements as well as targeting of the handle. The hip muscles including hip flexors and glutes work together to perform a smooth transition between catch and finish that generates the elegant stroke. In this subtle dance, leg adductors keep the body aligned, while the neck muscles help with a stable and neutral head position. That is why, the posture of a rower forms the basis of an excellent performance on the water or ergometer. As rowers get ready with the catch position, maintaining the straight and the upright torso, the engagement of core muscles not only supports their spine but also facilitates the transfer of power from the catch to the drive phase. Flexibility is a key factor in the process, allowing rowers to attain the necessary range of motion during each phase of the stroke. Flexibility of the body has this unique ability to make a smooth transition between the catch and the finish position resulting in a more powerful and efficient stroke. Additionally, inadequate flexibility in these areas could lead to the overexertion of muscles and joints in the spine and shoulders (Ettema et al., 2022;Buckeridge et al., 2015; Penichet et al., 2021;Stutchfield & Coleman, 2006).

In the literature, ıt has been shown that a lack of hamstring and hip flexibility may cause back and knee injuries in rowers rowers (Kasmi et al., 2017; Graham-Smith et al., 2007). To explain that, a term is used as a lumbopelvic rhythm represented by the pattern of a rowing stroke, which combines pelvic rotation with lumbar spine bending (Steer et al., 2006). Numerous studies indicated a significance of lumbopelvic coordination during rowing; rowers should prefer a complete range of pelvic movement rather than severe lumbar spine flexion to decrease stress on the spine (Bull & McGregor, 2000; Wilson et al., 2014). Therefore, Position the pelvis correctly throughout the stroke with adequate hamstring flexibility, reducing the need for additional lumbar movement (Smoljanovic et al., 2009). On the other hand, inadequate hamstring flexibility would restrict the pelvic range of motion and elevate lumbar spine involvement, particularly in the catch position.That is why, hamstring flexibility is a parameter that should be evaluated regarding rowers' performance as it affects the movement pattern during rowing (Weerts et al., 2019).

Another critical issue is the ankle flexibility of the rowers. There is a foot stretcher in the boat where the rowers put their feet, and it has been suggested that the more vertical foot stretcher leads to greater propulsive force on the boats. However, rowers' ankle flexibility can limit the shank and leg positions during the catch. More vertical foot-stretcher angle is supposed to greater dorsiflexion for the same amount of knee flexion. Because greater ankle flexibility allows the rower to relax, increase their speed and smoothness in and out of the water and thus maximize boat speed efficiency, foot stretcher angles, arranged based on the rower's flexibility, may provide athletes with enhanced performance while competing (Liu et al., 2020).

It has been proven in the literature that parameters such as power, balance, and endurance affect the performance of rowers. However, the findings examining the relationship between flexibility parameters and rowing performance are insufficient and the results are controversial, and the flexibility relationship of some regions is pathology dependent. In addition, to the best of our knowledge, there is no study in the literature that includes ankle flexibility (Stutchfield & Coleman, 2006; Graham-Smith et al., 2007). Knowing the relationship between lower extremities and low back flexibility with rowing performance is essential to focus on and improve the training programs to increase the rowers' performance, prevent injury, and sustain their sports careers for a long time. Therefore, this study aimed to investigate the relationship between lower extremity flexibility, including low back, hamstring, and ankle flexibility, and 2000-m rowing ergometer performance time in elite male rowers.

MATERIALS AND METHODS

Study Group

The study included 26 male rowers (mean age: 16.72±0.73 years) who competed in the Turkish Federation ergometer race. Inclusion criteria determined elite rowers with at least three years of experience. Athletes were excluded from the study if they had any back and lower extremity injuries and pain and attended any rehabilitation program. The mean body height was 1.86 meters, with a SD of 0.05 meters. Heights ranged from 1.7 to 1.9 meters among the participants while a mean body weight of 77.64 kilograms, with a SD of 9.89 kilograms. Individual body weights ranged from 55.3 to 94.1 kilograms. On average, participants had 3.00 years of rowing experience, with a SD of 1.14 years. Rowing experience varied, with a range from 2.0 to 5.0 years. The mean training frequency was 16.60 hours per week, with a SD of 8.93 hours. Participants engaged in training for a range of 6.0 to 42.0 hours per week (Table 1).

Before the assessment, all rowers were informed about the evaluation process and signed the informed consent form. Parent-informed consent was obtained for athletes who were younger than 18 years. After the purpose of the study was explained to Turkish Rowing Federation and team coaches the athletes were asked for their consent.

Ethics Statement

This study was approved by the decision of the Marmara University Clinical Research Ethics Committee by the Declaration of Helsinki (protocol number 182). The clinical trial number of the study is NCT05771272.

Protocol

Before evaluation process, a pre-structured questionnaire was filled out through face-to-face interviews to get their physical features (age, body mass index, presence of chronic diseases, and training habits). After filling out the form, the participants performed three tests, including the sit and reach test, weight-bearing lunge test and 2000-m rowing ergometer performance time test on the same day. All athletes with lower extremity flexibility, including lower back, hamstring, and ankle, were assessed. The low back and hamstring muscle flexibility was evaluated by the 'sit and reach test,' and the ankle flexibility was measured by the 'weight bearing lunge test.' In order to evaluate the performance of rowers, 2000-m rowing ergometer performance time test results were recorded after the race.

Procedures

Firstly, the flexibility of lower extremity tests were performed. Then, a warm-up of 6 min at a 500 m split time of 2 min 30 s was performed by all rowers before the 2000-m rowing ergometer performance time test. All rowers rested for 6 min, during which time they performed stretching exercises. The time to complete 2000 meters in the quickest amount of time was calculated and displayed on the ergometer. On the Concept II ergometer, stroke-by-stroke power output was recorded and stored in a file. The mean power output and time-trial time were computed for each ergometer race. The Sit and Reach Test is one of the linear flexibility tests that helps determine how extensible the hamstrings and lower back are (Mayorga-Vega et al., 2014). It was first introduced in 1952 by Wells and Dillon and is likely the most used flexibility test. In a study, the test was used to measure the flexibility of rowers. The box measured 32 centimetres in height, 45 centimetres in width, and 35 cm in length; the box's upper surface was 15 cm longer than the area where the feet rested. The subject was positioned on the ground with both legs fully extended, separated by shoulder width, and flat on the box. The participants positioned themselves with one hand on top of the other, knees fully extended, stretched as far forward as they could, sliding their hands across the ruler's top, and kept that posture for at least two seconds. The end location of the fingertips on or approaching the ruler was measured in centimetres to get the sit and reach score. Higher scores showed improved performance. The best result was recorded after the test was run thrice (Baltaci et al., 2003).

The Weight-Bearing Lunge Test, also known as the Dorsiflexion Lunge Test, measures the ankle joint's dorsiflexion. With a tape measure on the floor, measure the distance from the big toe's end to the wall. It was done on both legs. The subject's foot was on the floor with the big toe and heel line aligned on the tape measure. Following that, identical methods were used to test the other leg. They made a lunging motion forward until their knee hit the wall. The untested leg may be rested on the floor, and subjects could grip the wall during the test. To determine how close to the wall a subject could touch the wall with their knee while still keeping their heel in contact. The tape measure was then used to calculate the distance from the big toe's tip to the wall in centimetres. After the measurements, each participant's average of both legs was calculated (Powden et al., 2015).

Rowing performance was evaluated by a 2000-m time-trial on the Concept II rowing ergometer. The competitive racing setting was most likely where the rowers put their best effort. The rowers had to complete 2000 in the quickest amount of time. On the Concept II ergometer, stroke-by-stroke power output was recorded and stored in a file. The mean power output and time-trial time were computed for each ergometer race (Mikulić et al., 2009).

Table 1. The physical characteristics of the elite rowers (n=26)

Variables	Mean	SD	Range
Age (years)	16.72	0.7	16.0-18.0
Height (m)	1.86	0.05	1.7-1.9
Weight (kg)	77.64	9.89	55.3-94.1
Rowing experience (years)	3.00	1.14	2.0-5.0
Training frequency (hours in a week)	16.60	8.93	6.0-42.0

SD: Standard deviation

Data Analysis

Data were analyzed using SPSS version 26.0 and $p \leq 0.05$ was accepted as significance level. The degree of relationships between data variables is measured using correlation coefficients. Pearson correlation coefficients (r) were applied to determine the strength of each independent variable and their relationship to 2000-m rowing ergometer performance time test. A Pearson correlation coefficient, evaluated the the relationship of each independent variable with values range from -1 to 1 for a perfectly inverse, or negative, connection. Values close to zero suggest a lack of a linear relationship or an extremely weak association. The strength of the relationship is often described using the following values; If the coefficient value lies between ± 0.50 and ± 1, then it is said to be a strong correlation, If the value lies between ± 0.30 and ± 0.49, then it is said to be a medium correlation, when the value lies below + .29, then it is said to be a small correlation (Shober et al., 2018). After preliminary analysis, a stepwise multiple regression was conducted to examine the relationships between the predictor and outcome variables to identify the most significant predictors while controlling for other variables. The 95% confidence interval for β is accepted as the range of values for which a hypothesis test cannot be rejected at both the 5% significance level.

RESULTS

In this section of the study, statistical analysis results and interpretations of the data obtained are given.

The results of the anthropometric and flexibility parameter and their correlations with 2000-m rowing ergometer performance time test are shown in Table 2. There was a negative correlation between performance and anthropometric variables (height and body mass index) and training frequency. Although there was no correlation between sit and reach and 2000-m rowing ergometer performance time test results, ankle flexibility was negatively medium level correlated with 2000-m rowing ergometer performance time test results at the 0.05 significance level ($r = -0.39$; $p<0.05$). Additionally, 2000-m time is negatively medium level correlated with anthropometric variables (height and body mass index) and training frequency of rowers in a week (Table 2).

Table 2. Correlations of anthropometric and flexibility parameters with 2000-m rowing ergometer performance time test result

Variable	Correlation coefficient with E2000 * p
E2000 (s)	1
Age (years)	-.171 0.001
Height (m)	-.500 0.08
Weight (kg)	-.421 0.02
Body Mass Index (kg/m$^{2)}$	-,271 0.001
Rowing experience (years)	-.305 0.06
Training frequency (h)	-.469 0.03
Weight-Bearing Lunge Test (average of both ankles) (cm)	-.396 0.01
Sit and Reach Test (cm)	-.142 0.001

* Correlation coefficient: r, Correlation is significant at the 0.05 level (2 tailed): p. E2000: 2000-m rowing ergometer performance time test

Based on the stepwise multiple regression analysis results, the following variables were found to be significant predictors of the outcome variable: The training frequency increases, there is a significant negative effect on the outcome variable (The coefficient (Beta) =-0.382, t=-2.213, p=0.039). The other predictor variables, including weight, height, and ankle flexibility, were found to be non-significant predictors based on their p-values (p>0.05, the coefficient (Beta) for weight is -0.167, with a t-value of -0.719 and a p-value of 0.481; The coefficient (Beta) for height is -0.303, with a t-value of -1.377 and a p-value of 0.184; The coefficient (Beta) for ankle flexibility is -0.228, with a t-value of -1.270 and a p-value of 0.219). These findings suggest that weight, height, and ankle flexibility do not significantly affect the outcome variable. Therefore, in the stepwise multiple regression analysis, only training frequency was a significant predictor of the outcome variable, while weight, height, and ankle flexibility did not have a significant impact (Table 3).

Table 3. Stepwise multiple regression with 2000 m performance as the response variable

Variables	**B**	**SE**	**β**	**t value**	**p value**
Constant	889.288	225.072		3.951	**.001***
Weight	-.615	-.856	-.167	-.719	.481
Height	-193.579	140.615	-.303	-1.377	.184
Training Frequency	-1.554	.702	-.382	-2.213	**.039***
Ankle Flexibility	-2.129	1.677	-.228	-1.270	.219

* = statistically significant; B unstandardized coefficient; β=standardized coefficient; SE= Standard Error ; R^2 = .492; R = .39, significance level set at <0.05

DISCUSSION

The current study aimed to investigate the relationship between the hamstring, lumbar region, and ankle flexibility of rowers' and their 2000-m performance. The study provides valuable insights into the factors influencing 2000-m rowing ergometer performance. Ankle flexibility, anthropometric variables (body height and body mass), and training frequency all play roles in determining performance outcomes. Notably, the results highlight the significance of consistent training, as evidenced by training frequency emerging as the primary predictor of rowing performance.

Performance in rowing is affected by a variety of factors (Baudouin & Hawkins, 2004). Limited results have been sought in the literature for rowing performance and performance-related parameters. Physical fitness parameters are widely used to predict the performance characteristics of athletes in various sports. However, many factors determine performance in rowing (Mäestu & Jürimäe, 2005). Some of these factors are power, balance, endurance, and strength (Akça, 2014). Anthropometric measurements and parameters such as flexibility are essential factors in rowing performance. Identifying the strengths and weaknesses of the rowers in advance, which may affect their performance, is an important factor that determines the performance of the athletes in their matches (Soper & Hume, 2004). A rower's body composition has been indicated to be significant in determining performance (Ackland et al., 2012). The study by Bourgois et al., (2000) showed that elite junior male rowers have taller, more comprehensive, and girthier dimensions than a normative reference group of people their age. Since these differences in anthropometric measurements affect performance, the elite group of young male rowers found significant differences in length, width and circumference dimensions, and body mass between finalists and non-finalists (Bourgois et al., 2000). The study conducted by Kılınç (2008) reached the following conclusion: the group with high rowing performance had a height difference of 5.9 cm and a body weight difference of 2.7 kg more than the other group. It has been concluded that physical structure is effective in the rowing performance of puberty boys, especially extremity length and circumference values, which affect performance positively (Kılınç, 2008). In another study conducted on rowers aged between 12-13, higher levels of rowing performance were positively correlated with body size, particularly with sizeable lean body mass, including weight and height (Mikulić & Ryzic, 2008). The results in the literature showed that these results are consistent with our study findings. The current study revealed that 2000-m rowing ergometer performance time test result was negatively correlated with anthropometric variables. These findings imply that specific body features impact rowing performance, especially 2000-m ergometer performance. Therefore, when selecting adolescents for rowing teams, coaches may pay attention to those with large body sizes regarding height and weight.

Although the current studies report that exercise frequency does not affect muscle strength overall, it is essential for improving training programs. As the level of athletes increases, manipulation of training variables becomes more essential. One of the methods is that when the training level increases is to correspondingly increase the total weekly volume. This can be done differently by increasing load, weekly sets, and repetitions per set (Kraemer & Ratamess, 2004). When the total weekly sets for an athlete increase, it might be advantageous to spread volume over several training sessions, as suggested by Hartman et al. (2007). Exercising at a high volume per session can be less beneficial for maximizing muscle adaptations due to muscle fatigue. Thus, it can be effective to split the total training volume into several training sessions throughout the week to prevent potential increases in the fatigue of muscles (Johnsen & van den Tillaar, 2021). Based on these findings, our study also confirms this theory. This study revealed a negative correlation between training frequency and 2000-m rowing ergometer performance time, indicating that a higher frequency of training sessions was associated with improved performance in elite male rowers.

In a study conducted by Howell (1984), it was found that athletes with higher lumbar flexion flexibility may reach further forward and have a more extensive range of motion available to them to produce power throughout the drive. Moreover, Reid and Mcnair (2000) concluded that low back pain and decreased performance in rowers are also caused by restrictions in hamstring flexibility and joint hypermobility. On the other hand, our findings showed that no correlation was found between sit and reach test results and 2000-m time. The flexibility of the participants' hamstring and lower back does not significantly influence their performance in the 2000-meter rowing ergometer test. This finding implies that other factors, such as muscular strength, endurance, or technique, may play more prominent roles in influencing the participants' rowing performance over the specified distance.

As far as we know, no results for the relationship between 2000-m rowing ergometer performance time test and flexibility results specially for ankle flexibility in rowers were investigated in the literature. Our study found no significant relationship between hamstring, lumbar region and 2000-m rowing ergometer performance time. According to the literature, it has been determined that ankle flexibility can be effective in the performance of rowers, although there has yet to be a consensus in the literature. Soper and Hume (2005) examined the mechanics of rowers, power output, and the performance duration on the 2000-meter race ergometer, explicitly focusing on altering the foot stretcher angle. In the study, the power output improved when the foot-stretcher angle was increased from 36° to 46°. So, these results may imply rowers with better performance thanks to greater dorsiflexion (Soper & Hume, 2005). Our findings related to ankle flexibility demonstrated similarity that ankle flexibility results were negatively correlated with 2000-m rowing ergometer performance time test result at the 0.05 significance level ($r = -0.39$; $p < 0.05$). This means the rowers with greater ankle flexibility perform better in the 2000-m rowing ergometer performance time.

Limitations and clinical implications

The study was performed in 26 males rowers which is a relatively small sample which might restrict the generalizability of the finding. In the subsequent research, different gender and larger samples can be used. The study design is cross-section, which does not permit the establishment of causal relationships between the variables. Longitudinal research designs in future studies will allow an in-depth analysis of the intricate changes over time. The research was also not designed to determine the specifics of the rowers' training routines. Differences in the mode of training, such as intensity, duration and specific exercises may influence the observed connections. Further studies may potentially involve more detailed evaluations of training programs. Even with a few limitations to the study, there are still a number of clinical consequences of it. The investigation highlights it is the training frequency that determines the rowing performance in this regard. Coaches and players are able to use this or knowledge in a way of designing training programs targeted on a daily and nightly basis or even during weekends. While the ankle flexibility brought about only a slight drop in regression scores, its correlation with hesitation still indicates that the attention to the ankle flexibility would not be essentially in vain. Moreover, ankle flexibility could be included in the training schedule to be not the only target. Clinicians, physiotherapists, and coaches ought to approach the performance of rowers in a comprehensive manner rather than the lack of emphasis on a single biological or anatomical factor such as flexibility. This research may well be perceived to be a requirement for any training programs multi-directional evaluation for rowers, the induction process as well as the continuing education. According to the study, additional research can reveal various other risk factors and variables which could prove to be key contributors to solve the rowing performance problem. Addressing impact of psychological aspects, dedicated to technique perfection, and attentive to nutritional issues might result in a better comprehension of the factors that predetermine the success.

Conclusion

Greater ankle flexibility, larger body size, weigh, height, and weekly training frequency positively affect the 2000-m rowing ergometer performance time test in elite male rowers. Body weight and height are important factors that can be considered in sport-specific selection criteria. In addition, ankle flexibility is another parameter that can affect 2000-m performance time in elite rowers. Identifying these factors mentioned in elite rowers may be an effective strategy to increase performance. For this reason, we recommend that factors such as body size and ankle flexibility be considered before and after the season in rowers, and these parameters should be evaluated and followed to increase performance.

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Conflict of Interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethics Statement

This study was approved by the decision of the Marmara University Clinical Research Ethics Committee by the Declaration of Helsinki (Protocol number 182).

Author Contributions

Study Design, ETÇ; Data Collection, YB, DÖ and CS; Statistical Analysis, YB and DÖ; Data Interpretation, ETÇ, YB and DÖ; Manuscript Preparation, ETÇ, YB, DÖ CS and AY; Literature Search, ETÇ, DÖ, YB, CS and AY. All authors have read and agreed to the published version of the manuscript.

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