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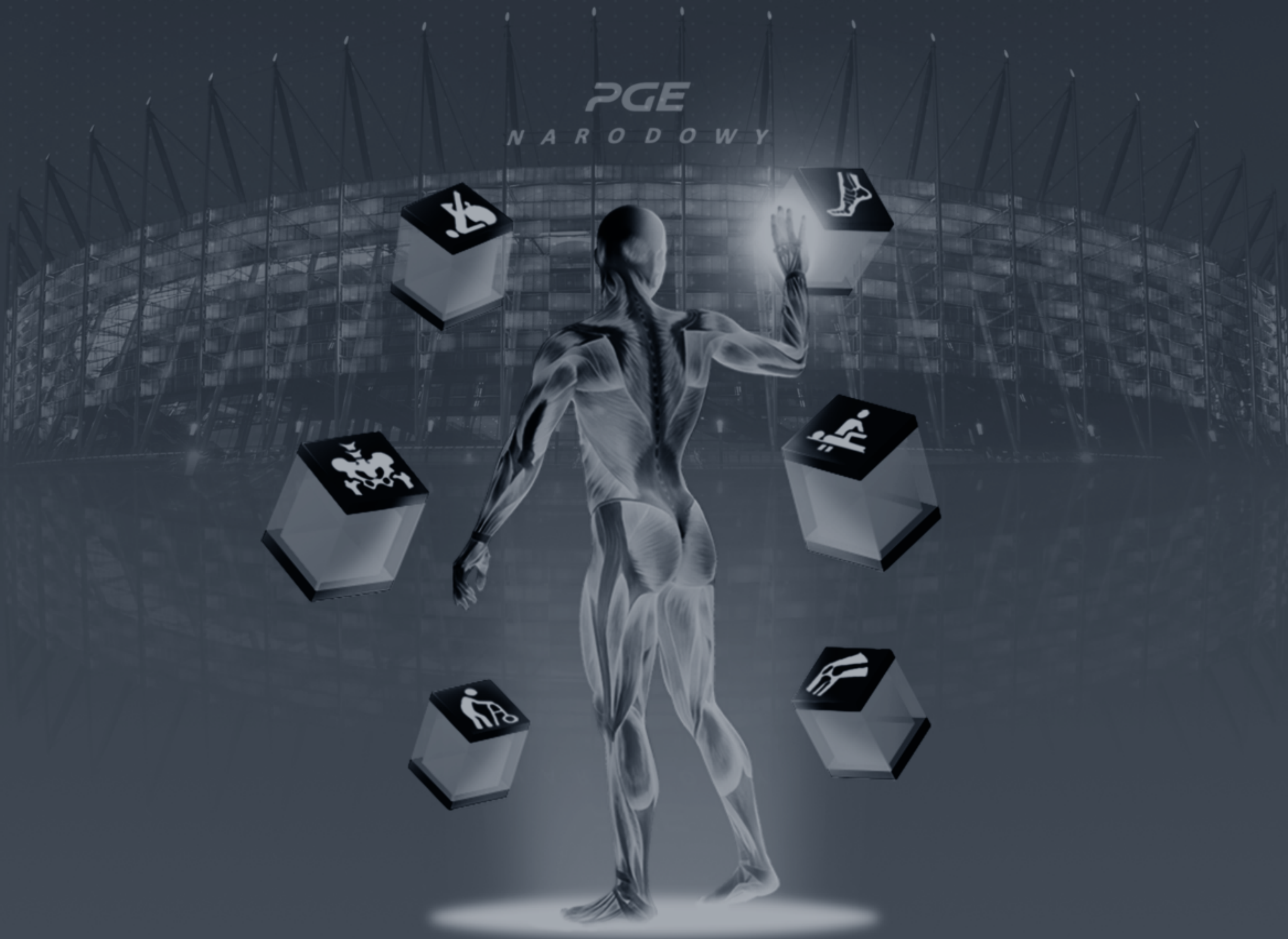

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Relationship between Hamstring Length and Gluteus Maximus Strength with and without Normalization in Patients with Mechanical Low Back Pain

Związek między długością ścięgna podkolanowego a siłą mięśnia pośladkowego wielkiego z normalizacją i bez normalizacji u pacjentów z bólem krzyża o podłożu mechanicznym

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Abstract
Background. Muscle strength is an important tool for the assessment of muscle function and is strongly influenced by body size. Therefore, utilization of strength body-size-independent measurements for muscle strength testing is important in comparing the strength measured in large populations. Mechanical low back pain is the commonest musculoskeletal disorder in clinical practice and is associated with gluteus maximus weakness and hamstring tightness. Objective. This study aimed to determine the correlation between hamstring length and gluteus maximus strength with and without normalization in patients with mechanical low back pain. Methods. Seventy-three patients diagnosed with mechanical low back pain participated in this study. First, gluteus maximus strength was measured isometrically as a force (kg) and then converted to torque (Nm). Gluteus maximus strength was normalized for body weight and height using the following formula:% (body weight × height) = torque (N × m) ×100 / body weight (N) × height (m), then the hamstring length was measured using the active knee extension test. Results. The study population consisted of 38 females and 35 males with mean age, body mass and height values of 31.42 ± 6.78 years, 75.63 ± 12.77 kg, and 170.43 ± 9.24 cm respectively. The Spearman product-moment correlation between hamstring length and gluteus maximus strength revealed that there was a positive strong correlation ($p < 0.05$) between hamstring length and gluteus maximus strength with and without normalization. Conclusion. Contrary to our expectations, there was a highly significant positive correlation between gluteus maximus strength (with normalization) and hamstring length, and a positive correlation between gluteus maximus strength (without normalization) and hamstring length.

Key words:
Hamstring length, Gluteus maximus strength, Normalization, Mechanical low back pain

Streszczenie
Informacje wprowadzające. Siła mięśni jest ważnym narzędziem oceny funkcji mięśni i silnie wpływa na nią rozmiar ciała. Dlatego wykorzystanie pomiarów siły niezależnych od rozmiaru ciała do testowania siły mięśni jest ważne przy porównywaniu siły mierzonej w dużych populacjach. Ból krzyża o podłożu mechanicznym jest najpowszechniejszym schorzeniem mięśniowo-szkieletowym w praktyce klinicznej i wiąże się z osłabieniem mięśnia pośladkowego wielkiego i uciskami ścięgien podkolanowych. Cel. Celem tego badania było określenie korelacji między długością ścięgna podkolanowego a siłą mięśnia pośladkowego wielkiego z normalizacją i bez niej u pacjentów z bólem krzyża o podłożu mechanicznym. Metody. W badaniu wzięło udział siedemdziesięciu trzech pacjentów, u których zdiagnozowano ból krzyża o podłożu mechanicznym. Najpierw mierzono izometrycznie siłę mięśnia pośladkowego wielkiego jako siłę (kg), a następnie przeliczano na moment obrotowy (Nm). Siłę mięśnia pośladkowego wielkiego znormalizowano względem masy ciała i wzrostu za pomocą następującego wzoru: % (masa ciała × wzrost) = moment obrotowy (N × m) × 100 / masa ciała (N) × wzrost (m), a następnie zmierzono długość ścięgna podkolanowego za pomocą aktywnego testu wyprostu kolana. Wyniki. Badana populacja składała się z 38 kobiet i 35 mężczyzn o średnim wieku, wskaźniku masy ciała i wzroście odpowiednio 31,42 ± 6,78 lat, 75,63 ± 12,77 kg i 170,43 ± 9,24 cm. Korelacja Spearmana między długością ścięgna podkolanowego a siłą mięśnia pośladkowego wielkiego wykazała istnienie dodatniej silnej korelacji ($p < 0,05$) między długością ścięgna podkolanowego a siłą mięśnia pośladkowego wielkiego z normalizacją i bez. Wniosek. Wbrew naszym oczekiwaniom istniała bardzo istotna dodatnia korelacja między siłą mięśnia pośladkowego wielkiego (z normalizacją) a długością ścięgna podkolanowego oraz dodatnia korelacja między siłą mięśnia pośladkowego wielkiego (bez normalizacji) a długością ścięgna podkolanowego.

Słowa kluczowe:
Długość ścięgna podkolanowego, siła mięśnia pośladkowego wielkiego, normalizacja, ból krzyża o podłożu mechanicznym

Introduction

Mechanical low back pain (LBP) is a very common and expensive health issue in the western world. It is defined as LBP not attributable to a specific pathology like deformities, osteoporosis, fractures, radicular pain, or infection [1, 2]. About 23% of the populations worldwide are suffering from mechanical LBP, with 24% to 80% of them having a recurrence at one year. The burden of disability due to LBP is expected to rise with an increase in an elderly population in the coming decades [3, 4].

Correlation between overweight and LBP was proved [5]. Hip muscle recruitment was altered due to LBP, demonstrating a distal-to-proximal muscle activation pattern in the lower limb compared to proximal-to-distal pattern in healthy subjects [6]. Chronic mechanical LBP is the commonest musculoskeletal condition in clinical practice. Pain and inactivity in chronic mechanical LBP patients can lead to tightness and weakness of gluteus maximus (GM) muscle fibers [7].

Page et al. (2010) reported that GM and hamstring muscles are synergists for hip extension, therefore if the GM is weak, the hamstring will act as a prime mover for the hip extension to compensate for GM weakness [8] Hamstring tightness will develop in patients with LBP as a compensatory mechanism for GM weakness because both muscles have common attachments to the ischial tuberosity and sacrotuberous ligament [9]. It was found that weak hip extensors or shortened back extensors might increase the probability of LBP occurrence. Also, hip extensors fatigued faster in patients with LBP than in normal populations. Therefore, we can conclude that the correlation between LBP and GM weakness is very important, as this muscle plays a significant role in force transformation from the lower limb up to the spine during upright activities [10].

Muscle strength is an important tool for assessing muscle function and physical fitness that is commonly evaluated in exercise, sport, and medical science and is strongly affected by body size [11]. Body weight (BW) has been recognized as an important scaling factor for measures of muscle force and strength [12]. The importance of this is apparent when comparing persons of different body sizes (i.e., athletes vs. nonathletic, men vs. women, young vs. old), or protocols where body mass (BM) could change between data collection periods (e.g., long-term treatment) [13].

Many studies performed normalization for hip strength on healthy people [13-16]. Only one recent study was conducted to assess the relationship between hamstring length and GM strength with and without normalization in healthy male subjects and found that GM strength with normalization was positively correlated with hamstring length, whereas GM strength without normalization was negatively correlated with a hamstring length. Also, this study revealed that normalization of GM strength by BW and height (H) is more applicable to elaborate the correlation with hamstring strength. The study recommended investigating this relation on patients with LBP for clinical implications [17].

To our knowledge, no study investigated the relationship between GM strength and hamstring length with and without normalization in patients with mechanical LBP, so this study aimed to investigate the relationship between GM strength and hamstring length with and without normalization in patients with mechanical LBP. These may have implications for the preventative and therapeutic care of patients with GM weakness and hamstring tightness. The results of this study would be beneficial to clinicians as hamstring-stretching exercises could be accompanied by the treatment of GM weakness.

Materials and methods

Study Design

This cross-sectional study was conducted at the Faculty of Physical Therapy, Misr University for science & technology, Egypt from September 2018 to August 2020. Patients who agreed to participate in the study were asked to sign an informed written consent form. The study was approved by the institutional ethical committee (number: P.T.REC/012/002047) of our faculty and registered at ClinicalTrials.gov (ID: NCT04562701). After using the results of the study of Lee & OH (2018) and making statistical analysis by the Pearson correlation test, the sample size was determined to be 73 with power 90, α error = 0.05, and effect size = 0.33.

Participants

Seventy-three patients (38 men, 35 women) participated in this study. All patients were diagnosed and referred by a physician according to the following criteria: (1) mechanical LBP with very high grade, measured by mechanical inflammatory LBP (MIL) index, (2) age range; 18-40 years, (3) body mass index (BMI) ranged from 25 to 30 kg/m^2. Patients who (1) had a history of previous fractures, surgeries, malignancies, or trauma to the back, (2) had rheumatoid arthritis, spondylosis, or spondylolisthesis, and (3) had a history of lower limb injuries were excluded from the study.

Anthropometric Measurements and GM Strength Testing

All procedures were performed during a single testing session. The anthropometric measurements including BW and height (H) were collected and BMI was calculated for every patient using the following formula: BMI = Weight (kg) / Heigth^2 (m^2) [18]. The femur segment length (m) was obtained by measuring the distance between the greater trochanter and the lateral epicondyle [19]. To measure GM strength, the patients were asked to lie in a prone position with a belt supporting the pelvis and knee flexed 90 degrees. A hand-held dynamometer (HHD) was secured with a non-elastic immovable strap just above the popliteal fossa. All participants were given verbal instructions to push with maximal force against the HHD for 5 seconds. Patients were instructed to do one practice trial then three trials were conducted for measurements with 2-minutes rest between each trial. The subject's hand was placed behind the waist to control the substitute motions of arms or hands. The peak force for each trial was recorded, and the average value was calculated [17].

Normalization Procedure

Peak force values (kg) were multiplied by 9.8 to be converted to Newton (N). Torque values (Nm) were calculated by multiplying the force values (N) by Femur Segment Length (m) [19]. The following formula: % (body weight × H) = torque (Nm) ×100 / body weight (N) × height (m) was used for normalizing muscle torque for BW and height (H) [17].

Assessment of hamstring length

The flexibility of hamstring was measured using the active knee extension (AKE) test, which has been proposed as the gold standard for assessment of hamstring flexibility. It offers a quick, reliable, and low-cost test for the measurement of hamstring flexibility [20]. The patient was positioned in a supine lying position with the non-tested limb flat (knee extended) and supported with a strap over the mid-thigh to eliminate any substitutive movement. Another strap was rapped over the pelvis for fixation. To maintain 90 degrees of the hip joint, a wooden frame was placed on the plinth in line with the participant's anterior superior iliac spine of the pelvis. The participant was instructed to flex the hip of the tested leg so that their thigh touching the wooden apparatus all over test time. The goniometer was used to measure the angle of knee extension in degrees indicating hamstring muscle length. The axis of the goniometer was placed over the lateral knee joint line with the moveable arm aligned with the lateral malleolus of the ankle and stationary arm aligned with greater trochanter parallel to the femur. The participant was then asked to straighten his knee as far as he can while maintaining the thigh touching the wooden apparatus. The participant was allowed to do one practice trial and then three measurements were recorded. The average of these three readings of the goniometer was recorded and was used as an indicator for hamstring flexibility [21, 22].

Statistical analysis

Statistical analysis was conducted using SPSS for Windows, version 23 (SPSS, Inc., Chicago, IL). The dependent variables (hamstring strength and normalized and non-normalized GM strength) were not normally distributed. Therefore, non-parametric tests in form of the Spearman product-moment correlation were used to determine the strength and direction of a linear relationship between hamstring strength and (normalized, non-normalized) GM strength. The significance level was set at $p < 0.05$. The level of correlation was determined using the following values: < 0.3 represented weak correlation, from 0.3 to 0.7 moderate correlation, and > 0.7 strong correlation.

Results

A total of 73 participants (38 females and 35 males) with mean age, BM, and H values of 31.42 ± 6.78 years, 75.63 ± 12.77 kg, and 170.43 ± 9.24 cm respectively. The Spearman product-moment correlation between (hamstring length and GM strength with normalization) revealed that there was a positive strong correlation ($p < 0.05$). This means that increase in the hamstring length is consistent with an increase in GM strength with normalization. Also, there was a positive strong correlation ($p < 0.05$) between (hamstring length and GM strength without normalization). This means that increase in the hamstring length is consistent with an increase in GM strength without normalization (Table 1).

Table 1. Correlations between hamstring length and GM strength with & without normalization

		GM strength with normalization	GM strength without normalization
HL	Spearman correlation coefficient (rho)	0.885	0.86
	p-value	0.0001*	0.00018*

*HL: Hamstring length; GM: Gluteus maximus;*significant at p < 0.05, p-value: Probability value*

Discussion

This study examined the relationship between hamstring length and GM strength with and without normalization in patients with mechanical LBP. Our current study found that there was a correlation between hamstring length and GM strength in patients with mechanical LBP, which is consistent with the proposed theory and findings of Van Wingerden et al. (2004), who reported that hamstring tightness could be a compensatory mechanism to provide sacroiliac stability in subjects with gluteal muscle weakness [9], and Page et al. (2010) who reported that GM and hamstring muscles are synergists for the hip extension that means if the GM is weak, the hamstring often acts as a prime mover to compensate for GM weakness [8] Besides, Hoffman et al. (2011) have explained lumbopelvic imbalance due to the inefficiency of muscles of the hip as a factor associated with the presence of LBP [23].

In the current study, there was a significant positive strong correlation between GM strength with normalization, so the normalization of GM strength by BW and H has the potential to lead to more appropriate conclusions and interpretations about its correlation with hamstring length. These results come in accordance with the existing evidence of Lee & Oh. (2018) who proved that GM strength with normalization was positively correlated with hamstring length [17].

In contrary to Lee & Oh. (2018) who found a negative correlation between hamstring length and GM strength without normalization [17], our study found a strong positive correlation. This can be attributed to the difference in population sample as they conducted their study on healthy young males. A more plausible explanation is the narrow range BMI used in our study (from 25 to 30 kg/m^2) that resulted in a decrease in the strength of the relationship between body size and GM strength

[24-26]. Therefore, our results contribute a clearer understanding of considering the influence of body size variations on the relationship between the tested muscle strength and body size and this may be the reason why we did not find different results between with and without normalization.

Further prove for the need for normalization to reduce the influence of body size on muscle strength is provided by the data comes from Bazett-Jones et al. (2011) who examined normalization of hip muscle strength (measured as force and torque) to BM to determine the suitable techniques for creating body-size-independent measures. They found positive relationships between BM and hip muscle strength (force & torque), so the need for normalization to reduce the influence of body size was confirmed [13]. Karavelioglu et al. (2017) demonstrated that without normalization, there were no significant differences in both absolute handgrip strength (HGS) measures between boys and girls. However, When the HGS values were normalized to BM (rationally & allometrically), the normalized HGS scores for boys were higher than girls [27].

The results of our study come in line with the hypothesis of McGrath (2019), who reported that it is important to normalize absolute grip strength (AGS) to BW-normalized grip strength (NGS) as a data processing technique that directly controls the role of relative mass in muscle strength capacity. Therefore, using NGS warrants discussion for determining the appropriateness of NGS relative to AGS, or other normalization techniques [12]. A similar pattern of results was obtained by the data from McGrath et al. (2020) who performed a study to compare absolute to BMI-normalized HGS. The results demonstrated the importance of putting the effect of body composition on muscle strength into consideration when assessing strength capacity [28].

We acknowledge that there are considerable discussions among researchers demonstrating the need for normalization to reduce the influence of body size on strength, but our results demonstrate that this is not necessarily true regarding the limitations of narrow-body size variations. All these findings confirm that the absence of strength normalization in studies aimed at distinguishing among individuals of similar body size may be acceptable, but the same approach applied to studies with individuals of quite different body sizes could lead to erroneous conclusions. In our current study, muscle strength (torque) was normalized for BW and H using the following formula: Normalized torque = torque (N × m) ×100 / body weight (N) × H (m) built on the existing work of Lee & Oh. (2018), who reported that force measurements could be normalized for BM without H, but for torque measurements, it is mandatory to be scaled to BM and H. This discrepancy is likely because the measurement of torque (in general) is more strongly related to body size variables (BM, fat-free mass, and H) [17].

Many studies planned comparisons between different normalization techniques for muscle strength revealed that the different normalization methods or lack of normalization resulted in different results [12, 13, 16, 19, 26, 28-30]. It is important to highlight the fact that ratio standard normalization for hip strength force by BM and hip strength torque by BM*H may be appropriate for removing body-size dependence in nonathletic, heterogeneous populations, which come in accordance with our study and the ideas of Bazett-Jones et al. (2011 & 2017) [13, 19].

It is also important to note that the present evidence relies on the allometry approach assumes that the relationship between biological variables (e.g., HGS) and anthropometric variables (e.g., BM) is nonlinear which is in agreement with many studies [11, 26, 31-33] and thereby using a power function to remove the BM effect is very important. On the contrary side, Jaric et al. (2005) revealed that torque does not require allometric scaling and added that normalization to BM and H is the most suitable method for normalizing torque [34]. Another promising finding by Crewther et al. (2009) & Thompson et al. (2010) was that allometric scaling is potentially a more effective method compared to ratio scaling for removing the influence of body size when comparing athletes with large BM variations. From this standpoint, normalization of hip muscle strength to BM and H can be considered as the most appropriate technique for normalizing torque of hip muscle, which was used in our study on patients with mechanical low back pain, with narrow BM variation [35, 36].

Conclusion

Contrary to our expectations, there was a significant strong positive correlation between GM strength with and without normalization and hamstring length. These results indicate that the absence of strength normalization in studies aimed at distinguishing among individuals of a limited range of body size may be acceptable, but it is mandatory to use normalization techniques in studies with individuals of quite different body size to eliminate the influence of body size on strength, which could lead to erroneous conclusions. In light of these findings, it is reasonable to assume that as the range of individuals' sizes increases, the strength of the relationship between strength and body size is likely to increase, indicating the need for normalization technique.

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Applicable remarks

- *Normalization of hip muscle strength to BM and H can be considered as the most appropriate technique for normalizing the torque of hip muscles.*
- *The absence of strength normalization in studies aimed at distinguishing among individuals of a limited range of body size may be acceptable.*
- *It is mandatory to strengthen hip extensors in patients with mechanical LBP.*

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