Do Hip and Ankle Strength as well as Range of Motion Predict Y-Balance Test - Lower Quarter Performance in Healthy Males?

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Do Hip and Ankle Strength as well as Range of Motion Predict Y-Balance Test - Lower Quarter Performance in Healthy Males?

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Abstract

The study aim was to evaluate associations between hip and ankle strength, ROM and YBT-LQ. The study involved 66 healthy males (age: 25.2±6.8 years). Each participant was assessed with ankle DF ROM, hip IR ROM, ER ROM and hip ABD, EXT and ER muscle isometric strength. The YBT-LQ test was performed for both limbs (stance and kicking leg). Forward two-step multiple linear regression analysis was performed to determine relationships between a predictor set and the criterion variable. Of 6 input variables for regression models, only 2 (ankle DF ROM, hip ABD strength) explained variance of YBT-LQ performance. Variance for anterior, posteromedial (PM) and posterolateral (PL) reach distances were explained from $R^2 = 0.15$ to $R^2 = 0.49$, but the models’ composition in PM and PL differed between legs. YBT-LQ composite score in both legs was explained by the same model, including ankle DF ROM and hip ABD ($R^2 = 0.44$; $R^2 = 0.25$). Hip ABD strength and ankle DF ROM assessment may be useful in individuals with poor YBT-LQ test performance to detect specific musculoskeletal deficits. Moreover, the regression models in stance leg for all reaches and composite score were more predictive than for the kicking leg.

Introduction

Sports injuries are a common problem, with an estimated prevalence from 3 to 5 million per year. Their majority occur in the lower limbs¹ and result in training or competition time loss, medical costs², psychosocial impairments³ and can contribute to sport career termination⁴. Therefore, prevention, the crucial component of which is screening⁵, plays a very important role in modern sport.

Dynamic balance is key component for almost all forms of physical activity⁶. Evidence suggests that its disturbance may be a factor increasing the risk of lower limb injury⁷,⁸. The most popular tool for dynamic balance assessment is the Y-Balance Test - Lower Quarter (YBT-LQ). This test is inexpensive, not time consuming and easy to apply. YBT-LQ has demonstrated good to excellent intra- and inter-rater reliability across studies with different populations⁹,¹⁰–¹¹. It has been reported that in high-school basketball players, the YBT-LQ composite score below 94% was considered as a cut-off value predicting injury in female athletes¹². These authors also found that a greater difference in anterior reach (ANT) distance between limbs than 4 cm, increased injury risk nearly 3-fold. Similarly, Smith et al.¹³ have shown that only anterior reach asymmetry >4 cm was associated with risk of non-contact injury among athletes. In college football athletes, the cut-off composite score totalling 89.6% was identified to increase risk of non-contact lower limb injuries 3.5-fold. According to De Noronha et al.¹⁴, normalised posterolateral (PL) reaches <80% have been linked to increased risk of ankle sprains.
However, there are also studies in which no association would be shown between YBT-LQ performance and risk of injury among athletes. The findings of Lisman et al. allow to suggest that YBT-LQ is not connected with increased risk of lower limb injury in high-school athletes. Furthermore, Lai et al. and Wright et al. also demonstrated that no reach asymmetry nor composite score can predict lower limb injury in collegiate athletes. Moreover, in some studies, it has been indicated the YBT-LQ to be a poor injury-predictive tool in specific sports populations such as American football and basketball players, or adolescent road cyclists. Plisky et al. suggested that the reason of inter-population differences in YBT-LQ’s predictive validity may be the lack of cut-off value adjustment. This supposition is consistent with the findings of the study by Lehr et al., who found that accurate injury risk identification is possible when cut-off value is adjusted for age, sex and sport specifics.

The YBT-LQ was primarily developed to assess dynamic postural control, however, there are other existing factors that also can potentially contribute to the test results. In current literature on the subject, we found a few studies in which researchers tried to identify factors predicting YBT-LQ performance. Some authors connected hip strength and ankle dorsiflexion range of motion (DF ROM) with YBT-LQ performance. Hip external rotation (ER) and internal rotation (IR) ROM have not been linked with the YBT-LQ yet, but they were suggested as a risk factor for various lower limb overuse injuries. We have included these hip and ankle factors in our analysis because they may be of use in clinical or sports practice as an additional measurement detecting a subject’s weaknesses potentially influencing functional performance. Nelson et al. demonstrated that ankle, knee, hip and trunk kinematics are important predictors of YBT-LQ performance. They also found that knee extensor and hip abductor strength explained ANT and PM (posteromedial) variation, while hip extensor strength explained variation of PM and PL reach distances. Chimera and Larson showed that DF ROM, foot sensation and perhaps arch height index may be factors related to YBT-LQ composite score. Moreover, Gabriner et al. reported that DF ROM and plantar cutaneous sensation may explain variance in the ANT reach, while ankle eversion strength and static balance explained variance in the PM and PL reaches.

To the best of our knowledge, there are no studies in which hip and ankle joint strength and range of motion would be included as factors in one predictive model explaining performance in the YBT-LQ, separately for kicking- and stance leg. Therefore, we hypothesised that if the YBT-LQ is a reliable and valid tool, recognising which functional components may affect performance in this test, their detailed assessment may help in better understanding mechanisms of lower limb injuries. Thus, the objective of this study was to evaluate associations between hip and ankle joint strength as well as ROM and YBT-LQ performance separately for kicking- and stance leg in healthy males.

**Results**

There were no differences between stance and kicking leg in YBT-LQ performance (Table 1).

<table>
<thead>
<tr>
<th>Mean (SD) [Min-Max]</th>
<th>Stance leg</th>
<th>Kicking leg</th>
<th>Difference of mean</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior reach (%)</td>
<td>66.79 (5.97) [53.76-77.7]</td>
<td>66.53 (6.56) [51.81-76.67]</td>
<td>0.25</td>
<td>0.82</td>
</tr>
<tr>
<td>Posteromedial reach (%)</td>
<td>115.21 (7.03) [95.00-131.09]</td>
<td>114.65 (7.89) [91.67-132.20]</td>
<td>0.56</td>
<td>0.67</td>
</tr>
<tr>
<td>Posterolateral reach (%)</td>
<td>111.63 (8.24) [89.24-127.84]</td>
<td>112.23 (8.15) [92.39-127.68]</td>
<td>-0.41</td>
<td>0.68</td>
</tr>
</tbody>
</table>
There was substantially greater hip IR ROM and smaller ER ROM in stance compared to kicking leg (Table 2).

**Table 2. Hip and ankle strength and range of motion**

<table>
<thead>
<tr>
<th>Mean (SD) [Min-Max]</th>
<th>Stance leg</th>
<th>Kicking leg</th>
<th>Difference of mean</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle DF ROM (°)</td>
<td>42.73 (4.88) [31.00-53.67]</td>
<td>42.49 (5.10) [33.00-52.33]</td>
<td>0.24</td>
<td>0.79</td>
</tr>
<tr>
<td>Hip IR ROM (°)</td>
<td>37.10 (11.35) [15.33-67.00]</td>
<td>25.32 (9.97) [1.67-54.33]</td>
<td>11.78</td>
<td>&lt;0.05*</td>
</tr>
<tr>
<td>Hip ER ROM (°)</td>
<td>44.50 (11.51) [24.00-73.00]</td>
<td>61.44 (10.64) [25.33-87.00]</td>
<td>-16.93</td>
<td>&lt;0.05*</td>
</tr>
<tr>
<td>Hip ER strength [Nm/kg]</td>
<td>0.86 (0.14) [0.57-1.16]</td>
<td>0.90 (0.13) [0.61-1.18]</td>
<td>-0.04</td>
<td>0.11</td>
</tr>
<tr>
<td>Hip EXT strength [Nm/kg]</td>
<td>1.05 (0.26) [0.62-1.92]</td>
<td>1.12 (0.24) [0.71-1.91]</td>
<td>-0.07</td>
<td>0.11</td>
</tr>
<tr>
<td>Hip ABD strength [Nm/kg]</td>
<td>1.81 (0.31) [1.15-2.76]</td>
<td>1.81 (0.31) [1.15-2.76]</td>
<td>0.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Regression models in our study explained from 15 to 49% of YBT-LQ performance variance. Models in stance leg for all reaches and composite score were more predictive than kicking leg. Differences between legs were shown for PM and PL in the number of predictors included in models. Variables included in the final forward two-step linear regression for predicting YBT-LQ performance are presented in Table 3.

**Table 3. Variables included in liner regression models for predicting YBT-LQ performance**

<table>
<thead>
<tr>
<th>Included variables</th>
<th>β₀ (SE)</th>
<th>β₁ (SE)</th>
<th>ε</th>
<th>R²</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANT-SL (%) Ankle dorsiflexion-SL [°]</td>
<td>0.83 (0.11)</td>
<td>31.91 (4.61)</td>
<td>4.09</td>
<td>0.49</td>
<td>&lt;0.05*</td>
</tr>
<tr>
<td>ANT-KL (%) Ankle dorsiflexion-KL [°]</td>
<td>0.75 (0.13)</td>
<td>34.74 (5.70)</td>
<td>5.38</td>
<td>0.33</td>
<td>&lt;0.05*</td>
</tr>
<tr>
<td>PM-SL (%) Hip abductors-SL [Nm/kg]</td>
<td>9.41 (2.45)</td>
<td>98.49 (4.51)</td>
<td>5.97</td>
<td>0.19</td>
<td>&lt;0.05*</td>
</tr>
<tr>
<td>PM-KL (%) Hip abductors-SL [Nm/kg]</td>
<td>10.58 (2.24)</td>
<td>73.49 (7.76)</td>
<td>5.41</td>
<td>0.35</td>
<td>&lt;0.05*</td>
</tr>
<tr>
<td>PL-SL (%) Hip abductors-SL [Nm/kg]</td>
<td>10.41 (2.72)</td>
<td>95.61 (5.09)</td>
<td>6.25</td>
<td>0.19</td>
<td>&lt;0.05*</td>
</tr>
<tr>
<td>PL-KL (%) Hip abductors-SL [Nm/kg]</td>
<td>12.43 (2.39)</td>
<td>90.21 (4.42)</td>
<td>5.74</td>
<td>0.32</td>
<td>&lt;0.05*</td>
</tr>
<tr>
<td>CS-SL (%) Ankle dorsiflexion-SL [°]</td>
<td>0.68 (0.12)</td>
<td>53.81 (6.30)</td>
<td>4.38</td>
<td>0.44</td>
<td>&lt;0.05*</td>
</tr>
<tr>
<td>CS-KL (%) Ankle dorsiflexion-KL [°]</td>
<td>0.47 (0.15)</td>
<td>78.04 (6.23)</td>
<td>5.89</td>
<td>0.15</td>
<td>&lt;0.05*</td>
</tr>
</tbody>
</table>
Ankle dorsiflexion-KL [°] 0.47 (0.14) 64.38 (7.13) 5.47 0.25 <0.05*
Hip abductors-KL [Nm/kg] 7.53 (2.30)

β^0 – free parameter, β^1 – directional coefficient, SE – standard error, ε – standard error of estimation, R^2 – determination coefficient, NA – not applicable, p-value – probability of type I error, * – statistically significant model

**Input variables:** ankle dorsiflexion ROM [°], hip internal rotation ROM [°], hip external rotation ROM [°], hip external rotator strength [Nm/kg], hip extensor strength [Nm/kg], hip abductor strength [Nm/kg]

**Discussion**

This is the first study in which a report has been provided on the association between hip and ankle joint strength as well as range of motion using the YBT-LQ for performance. The most important finding of this study was that ankle DF ROM and hip ABD strength explain a large part variability of performance in the YBT-LQ. Moreover, regression models in stance leg for all reaches and composite score were more predictive than kicking leg.

Ankle DF ROM appears to be crucial for YBT-LQ performance, especially during ANT reach distance. The results of our study indicate this factor as a significant predictor of all reaching directions and composite score, but for PM and PL normalised reaches, this was only predictive for stance leg. In the most current studies, similar results have been demonstrated when considering ankle DF ROM as a predictor of ANT\textsuperscript{26,32,33} and PM reach distance\textsuperscript{6}. In the study by Chimera and Larson\textsuperscript{31}, only the left limb regression model, including ankle DF ROM significantly explained 22% of the YBT-LQ composite score variance, however, additionally higher DF ROM values predicted lower composite score. This differs from our observations, but we have suggested that this discrepancy may have occurred due to the smaller sample size and no dividing regression models into directional reaches in the mentioned research. In the study by Kang et al.\textsuperscript{33}, ankle DF ROM explained 50% of normalised ANT reach variance for the non-dominant leg (described as opposite to the kicking leg), which maintains in agreement with our present study in which we found an almost identical 49% for stance leg. It should be noted that in our study as in others\textsuperscript{26,32}, participants were not allowed to lift their heel during the ANT reach, which may have possibly caused overestimation regarding the predictive value of ankle DF ROM. On the other hand, Robinson and Gribble\textsuperscript{34} also forbade heel lift, which is why their final kinematic model for ANT reach distance did not include ankle dorsiflexion. Despite the YBT-LQ being a commonly used functional assessment tool, there are still some inconsistencies in methodology across studies that makes comparison difficult. In some studies, it has been indicated that ankle dorsiflexion ROM deficits may affect lower limb landing biomechanics\textsuperscript{35}. This could cause compensatory movement patterns in the biokinematic chain, for example, during weight bearing activities\textsuperscript{36,37}, which may further cause an increase in injury risk.

Hip ABD strength has previously been shown as a significant predictor of YBT-LQ performance.\textsuperscript{6,23,25} In our study, the contribution of hip ABD strength in regression models for PM and PL reaches and composite score ranged from R^2 = 0.10 to 0.32. Our results are comparable with those obtained by Wilson et al.\textsuperscript{21}. In their study, hip ABD strength explained about 10 to 16% of YBT-LQ performance. In Nelson’s\textsuperscript{6} kinetic model, hip ABD moment explained 23.4% of PM reach distance whereas PL direction performance was not predicted by hip ABD moment. The findings achieved by Dominguez-Navarro et al.\textsuperscript{25} also indicated that hip abductor strength was a significant predictor of composite score in young elite female basketball players. However, these results were only significant for right limb and, moreover, they analysed prediction of composite score without splitting into directional reaches. Our study maintains in agreement with those by Wilson et al.\textsuperscript{23} and Nelson et al.\textsuperscript{6}. The importance of hip ABD strength for YBT-LQ performance may arise from pelvic stabilisation...
function by resisting forces of gravity on the unsupported reaching leg. Due to the fact that the YBT-LQ requires a series of single leg squat manoeuvres, the hip abductor muscle function during single leg activities is crucial\textsuperscript{38,39}. Hip ABD strength weakness has been shown as a risk factor for knee\textsuperscript{40,41} and ankle injuries\textsuperscript{42,43}. One of the explanations is that this muscle group could prevent falling of the lower limb into excessive valgus alignment, e.g. during landing\textsuperscript{44}. However, these mechanisms are still under debate because human movement appears to be more complex than that linear\textsuperscript{45,46}. Nonetheless, it has been suggested that despite unclear mechanisms, hip strengthening programmes may improve dynamic balance\textsuperscript{47}.

In our study, out of 6 input variables used for regression models, only 2 (ankle DF ROM, hip ABD strength) explained variance of YBT-LQ performance. In the present study, hip extensor and external rotator strength were not predictive of YBT-LQ performance, which is consistent with the results achieved in the study by Wilson et al.\textsuperscript{23}, but from the findings obtained by Nelson et al.\textsuperscript{6}. In their study, kinetic hip extensor moment was the most significant predictor of PM and PL reaching distances. These contradictory results may be caused by the different measurement methods applied - hip strength versus hip moments. In our study and in that by Wilson et al.\textsuperscript{23}, hip strength was assessed in static, isolated position, while Nelson et al.\textsuperscript{6} collected hip moments during functional assessment of YBT-LQ, which could have caused those variables to be more predictive in regression models because measurements were taken simultaneously. It should be assumed that the predictive value of YBT-LQ performance is probably relatively higher in kinematic or kinetic models\textsuperscript{6,33,34} than when regression models include variables from less sophisticated tools as in our study. Nevertheless, isolated strength assessments performed with a hand-held dynamometer or range of motion measurements taken with an inclinometer are quicker, less expensive and easier to use in sport or clinical practice than motion capture systems. To our knowledge, the present study is the first in which hip internal and external rotation ROM have been verified as useful predictors of YBT-LQ performance. However, these variables did not turn out to be predictive in the model.

One of our most wondering findings was the noticeable higher predictive values of YBT-LQ performance in stance rather than kicking leg. A similar situation was noted in studies by other authors\textsuperscript{25,31}, who suggested that regression models were significant for only one leg. In the remaining trials, only measurements and analysis were considered for one limb instead of both probably due to the belief that balance does not differ significantly between the dominant and non-dominant limbs\textsuperscript{48}. However, as was observed in our study, regression analysis carried out separately for the assessment of each leg could differ between sides and this should be more extensively evaluated in future studies. We have suggested that these differences may arise from divergent anticipatory balance strategies\textsuperscript{49}. It is probable that stance leg, due to due to smaller centre of pressure (COP) displacements, could effectively utilise ankle strategy with only a gentle addition of hip strategy. On the other hand, the kicking leg appears to utilise a more proximal hip strategy due to greater COP displacements during single leg stance.

The findings of our study have significant clinical applications. By demonstrating that ankle DF ROM and hip ABD strength are predictors of YBT-LQ performance, it may be assumed that these factors translate into functional status. The screening of these factors could play a role in injury prevention programmes, especially for individuals with poor YBT-LQ performance. Moreover, we expect that hip abductor strengthening programmes should improve both strength and dynamic balance, which could potentially decrease future injury risk. In our study, we only assessed a healthy male population, but ankle dorsiflexion ROM may be an even more important physical component for people with ROM deficits, e.g. following ankle sprains or in instability. In such cases, the implementation of physical therapy interventions focused on restoring full ankle ROM should improve dynamic postural control.
There are also some limitations of this study. We examined only healthy males, thus, the results cannot be generalised to other populations, e.g. females, athletes or patients with specific injuries. Moreover, we adopted the two-step regression model, but the addition of more predictors (which would require an increase sample size) could shed new light on this issue.

Conclusions

Assessment of hip abductor strength and ankle dorsiflexion ROM may be a useful addition to the interpretation of tests in subjects with poor YBT-LQ performance. It may allow for more comprehensive detection of functional deficits related to poor dynamic balance and could potentially indicate adequate corrective interventions. Moreover, the different regression results observed between the stance and kicking legs for PM and PL reach distances may suggest the existence of some asymmetries within the body, which may further lead to increased risk of injury. Therefore, in the future research, it would be interesting to more comprehensively examine the source of observed asymmetry, and also, include more variables in the regression model, such as ankle plantar flexor, invertors and evertor, as well as knee strength.

Materials and methods

Participants

The study involved 66 healthy males (age: 25.2±6.8 years.; body height: 178±7.1cm; body mass: 75.8±10.2kg; BMI: 23.8±2.6). The inclusion criterion was age from 18 to 40 years. The exclusion criteria were: (i) lower limb massive injuries in the past (anterior cruciate ligament rupture, hip fractures, instability and recurrent ankle sprains); (ii) minor lower limb injury in the 3 months prior to examination which could enable the performance of the YBT-LQ; and (iii) diagnosed difficulties in maintaining balance. The sample size (n=66) was calculated according to the proposal by Green

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(sample size=50+8×number of predictors). The participants were informed about the research protocol in detail and gave their written informed consent to participate in the study. All procedures were performed in accordance with the 1964 Helsinki declaration and its later amendments. The approval of the Bioethics Committee at the Regional Medical Association in Krakow (No. 11/KBL/OIL/2022) was obtained for this study and for whole experimental protocol.

Study design

Prior to physical assessment, anthropometric measurements such as body mass, height and limb lengths were collected. In all participants, ankle joint dorsiflexion ROM, hip internal and external rotation ROM, hip abductor, extensor and external rotator strength were bilaterally evaluated. Then, subjects performed the YBT-LQ. Before each test, subjects was familiarised with testing procedure. The order of the tests was the same for each subject. Participant’s stance leg was determined as the opposite of self-preferred leg for kicking the ball

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. All measurement were conducted at a similar time of the day to avoid influence of circadian rhythm on sense of balance control. Each measurement was carried out by 1 experienced researcher. Every participant was instructed not to consume stimulants (e.g. caffeine) and/or alcohol on the day of testing and not to perform vigorous exercise 36-48 hours prior to testing.

Anthropometric measurements

Body high was measured with a stadiometer (Metrisis, Greece). Body mass was determined using the MC 780 MA analyser (Tanita, Japan). Body mass index was calculated as weight divided by height in metres squared. Lower limb length and the arm of force measurements were carried out with a measuring tape (TK Gruppe Klingler, China) to the nearest 0.5cm.
Range of motion assessment

Range of motion (ROM) assessment was performed using the Baseline digital inclinometer (RMS UK Ltd., UK). The mean of 3 measurements was considered for analysis. Ankle dorsiflexion ROM was measured during the Weight Bearing Lunge Test (WBLT) using the protocol described by Bennell et al. The participant stood facing the wall with his hands touching it. Each subject was instructed to maximally move the knee forward without lifting the heel off the ground. The inclinometer was placed 15cm below the tibial tuberosity to define maximal shank inclination (Figure 1). Passive internal and external hip rotation ROM were measured following the protocol proposed by Carvalhais et al. The participant was in prone position on a treatment table with the knee flexed to 90°. The participant’s pelvis was additionally stabilised on the table by a rigid strap to minimise lumbopelvic compensatory movements during hip rotations. The examiner performed passive hip rotation until tension of the muscles and passive structures of the hip joint stopped this movement. The inclinometer was placed on the lateral shank side for external hip rotation (Figure 2) and on medial shank side for internal hip rotation (Figure 3).

Isometric strength assessment

Isometric strength assessment was performed using the MicroFET2 hand-held dynamometer (Hoggan Health Industries Inc., USA). The participant’s pelvis was stabilised on table by a rigid strap to minimise lumbopelvic compensatory movements during trials. The participant performed 3 maximal isometric contractions for 5 seconds each, with a 15-second interval for rest between trials. The mean of 3 measurements was considered for analysis. Average force value was multiplied by force arm length and normalised to body mass (Nm/kg). Hip external rotator strength was assessed in prone position with 90° knee flexion using the protocol described by Mendonça et al. The dynamometer was placed proximally to the medial malleolus. Force arm length represents the linear distance from dynamometer placement to hip axis of rotation (Figure 4). Hip extensor strength was measured in prone position with the knee flexed to 90° according to Thorborg’s et al. protocol. The dynamometer was proximally placed 5cm to knee joint line on the posterior thigh. Force arm length represents the linear distance from dynamometer placement to the greater trochanter (Figure 5). Hip abductor strength was measured in side-lying position using the protocol proposed by Bittencourt et al. The dynamometer was placed proximally to the lateral femoral condyle. Force arm length represents linear distance from dynamometer placement to the greater trochanter (Figure 6).

Y-Balance Test – Lower Quarter

Each participant performed 6 training and 3 testing trials in each directions (ANT, PL, PM) for both stance (SL) and kicking leg (KL) using the Y-balance test kit (Move2Perform, USA). Training and testing trials were separated by a 1-minute interval for rest. Prior to performing the trials, all participants received verbal instruction and visual demonstration. Each participant performed single leg stance barefoot on a starting block. They used the opposite leg as the reaching leg to push the reach indicator box as far as possible in the following directions and in the following order: ANT, PM and PL. Attempts
did not count if the participant was unable to maintain single leg balance throughout the movement, lost hand contact from the pelvis, kicked the indicator box, lifted the heel during ANT reach or did not return to centre position with maintained balance. The mean of 3 testing trials in each direction was used for further analysis. Scores were calculated by dividing average reach distance (in cm) by participant’s leg length, which was measured in supine position from the anterior superior iliac spine to the medial malleolus. To calculate the composite score sum of average reaches in each of the 3 directions, this was divided by 3 leg lengths and multiplied by 100%. Normalised reach distance was calculated as the mean reach distance divided by leg length and multiplied by 100%.

**Statistical analysis**

Statistical analysis was performed using PQStat v. 1.8.4 (PQStat Software Company, Poland). Differences in measured variables between the kicking and stance leg were evaluated with the t-test for independent samples. The normality of distribution was examined via the Shapiro-Wilk test. Levene’s test was used to assess the equality of variance. Forward two-step multiple linear regression analysis was performed to determine correlations between a set of predictor and criterion variables. The linear relationship assumption between the predictor and criterion variables was checked before analysis. In addition, following assumptions about the models’ residual was verified: normal distribution (using the Shapiro-Wilk test), homoscedasticity (using White’s test), no multicollinearity (model inspection was performed when variance inflation factor was>5), no autocorrelation (using the Durbin-Watson test). The probability of type I error below 0.05 was adopted as the level of significance.

**References**


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**Data Availability Statement**

The raw data supporting the conclusions of this article will be available from the corresponding author upon reasonable request.

**Author Contributions**

M.O. - study concept and design, participant recruitment, data collection, literature search, data analyses and interpretation, writing and editing the manuscript. B.Z. - study concept and design, participant recruitment, literature search, statistical analyses, data analyses and interpretation, writing and editing the manuscript. A.M. - study concept and design, data interpretation, editing the manuscript. J.G. - study concept and design, data interpretation, editing the manuscript. All authors have read and agreed to the published version of the manuscript.

**Competing Interests**

The authors declare no conflict of interest. The funders had no role in the design of the study, in the collection, analyses or interpretation of data, in the writing of the manuscript or in the decision to publish the results.
Figures

Figure 1
Figure 2