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The relationship between concentric hip abductor strength and the performance of the Y-balance test (YBT)

Key Points

- Hip abductor strength is moderately associated with single leg dynamic balance as measured by the YBT.
- The association between hip strength and single leg dynamic balance is strongest during the posterior reaches of the YBT.
- The requirement for greater hip flexion, during the posterior reaches may impose greater demands on the hip extensors and abductors to control the movement.
- Targeting the hip abductor muscles as part of multi-level intervention is warranted when attempting to improve dynamic single leg stability.

Key words: single leg, dynamic postural stability, gluteus

Abstract

Side lying hip abduction is an action used during manual muscle testing and is also prescribed as a rehabilitation exercise to improve dynamic single leg stability. Little is known about the functional cross-over of this activity. The aims of this study was to investigate the relationship between concentric hip abductor strength and performance of the Y-Balance test (YBT). Forty-five recreational gym users (27 male age 26.2 (8.4) years, 18 female age 27.4 (7.5) years) had dynamic single leg stability and concentric hip abductor peak torque assessed in the non-dominant limb using a YBT and isokinetic dynamometry, respectively. All components of the YBT had a moderate association with concentric hip abductor torque which were greater in the posteromedial ($r=0.574$, $P<0.001$) and posterolateral ($r=0.657$, $P<0.001$) directions compared to the anterior direction ($r=0.402$, $P=0.006$). Greater concentric hip abductor strength is associated with greater scores on components of the YBT, particularly the posterior reaches.

Introduction

In static conditions, balance is defined as the ability to maintain the centre of gravity over a base of support.[1] Athletic activities such as running require the centre of gravity (position and velocity) to be maintained in the upright position despite a changing and moving base of support.[2] Hip abductor torque is thought to play an important role in stabilizing the trunk and pelvis. The hip abductors maintain lower limb alignment through reducing accelerations of the centre of mass in the sagittal and frontal plane in response to postural perturbations.[3,4] Compared to healthy controls, individuals with lower extremity injury such as chronic ankle instability (CAI),[1] anterior cruciate ligament (ACL) injury[5] and patellofemoral pain syndrome (PFPS)[6,7] have been reported to have reduced dynamic single leg stability. Hip abductor dysfunction is thought to contribute to poor lower extremity control by allowing knee valgus which occurs as a result of coupled adduction and internal rotation of the femur.[8] Greater knee valgus during dynamic tasks has been reported in those with acute (ACL)[9] and chronic (PFPS)[10] injury, compared to healthy controls. Furthermore, individuals with hip abductor dysfunction tend to lean towards the side of dysfunction to balance the centre of gravity on the hip joint centre,[8] further reducing the demand of the hip abductors on the stance leg. This position likely contributes to increased knee valgus, altering of the centre of pressure relative to the ankle joint and leading to increased demand on muscles of the lower leg.[3]

The hip abductors, most notably tensor fascia latae, gluteus minimus, medius and maximus, concentrically abduct the hip, isometrically stabilise the pelvis and eccentrically control hip adduction and internal rotation.[11] Increasing isometric hip abductor strength is associated with greater dynamic single leg stability. Previously, both Hubbard et al. and Lee et al. have demonstrated a moderate to strong association ($r=0.49 – 0.72$; $P<0.05$) between isometric hip abduction strength and performance of the posterior reaches of the Y-balance test (YBT).[12,13]

Open kinetic chain side lying hip abduction has been shown to elicit levels of muscle contraction (>70% of maximum voluntary contraction (MVC)) in line with that required to achieve strength gains.[14,15] However, to date, little is known about whether hip abductor strength whilst side-lying in a non-weight bearing position is associated with enhanced single leg stability in a weight-bearing position. Isokinetic dynamometry is a criterion method for the assessment of a MVC as it is subject to less confounding variables than that of handheld dynamometry such as examiner strength, the inability to correct for gravity and stabilisation techniques used.[16] Furthermore, peak torque from a voluntary muscle contraction can be measured within a coefficient of variance of 5%.[17] Many studies have assessed hip abductor strength using handheld dynamometers,[12,18-20] comparatively few have used isokinetic dynamometry.[6,21] Furthermore, variance in participant positioning, protocol for assessment as well as the criteria for the acceptance of peak torque measured from a MVC has varied widely among researchers. The Star Excursion Balance Test (SEBT) has emerged as a time and cost effective method of quantifying single leg dynamic balance with established reliability.[22] An instrumented version of the modified SEBT is known as the Y-balance test (YBT) and has been shown to measure balance in the anterior and posterior reach directions.[23] Whilst Coughlan et al.[24] identified that participants could reach further in the anterior direction of the SEBT, no difference in posterior reaches was found when compared to the YBT, suggesting posterior reaches are comparable with existing literature.

To the authors knowledge there has yet to be a study which assesses the relationship between concentric hip abductor strength and single leg dynamic balance as measured by isokinetic dynamometry and the YBT test respectively. It is plausible that those with lower hip muscle strength will have a lower capability of performing the YBT, particularly the posterior reach directions, due to an inability to eccentrically control the required hip flexion.[8] The aim of this study was to assess whether there is an association between concentric hip abductor strength and single leg dynamic balance in a convenience sample of healthy recreational gym users aged 18 – 35 years. We hypothesize that greater hip abductor torque will be associated with greater scores on the YBT, particularly in the posterior reach directions.

Methods

Participants

This study employed a cross-sectional study design in which participants reported to the laboratory for a single data collection session. A convenience sample of forty five participants (27 male, age 26.2 (8.4) years, height 173.3 (6.7) cm, weight 71.3 (9.9) kg and 18 female, age 27.4 (7.5) years, height 169.3 (5.9) cm, weight 65.3 (9.9) kg) all of whom were recreationally active at a local health and wellbeing centre or the University sports centre were recruited to the study. The definition of a recreational gym user was anyone who took part in gym based or group exercise activities at least three times per week.[25] Participants were required to be free from lower extremity injury for at least 6 months prior to testing, have no history of hip, knee or ankle surgery and be free from illness, such as influenza. These factors may influence strength and balance assessments and were excluded as potential cofounding variables. After receiving a complete explanation of the procedures, benefits and risks of the study, all participants gave their written informed consent. Participants were asked to refrain from strenuous exercise in the 24-hours before testing. All procedures were performed in accordance with the most recent version of the Declaration of Helsinki and approved by the Research Ethics Committee of the University of St. Mark and St. John.

Instrumentation Performance of the Y-balance test was conducted using a Y-Balance Test Kit (Functional Movement Systems, Virginia, USA) as illustrated in Figure 1. Peak torque of the non-dominant limb was determined from a MVC (30°/s) of the hip abductors using a commercially available dynamometer (Figure2; Humac Norm, CSMI, Massachusetts, USA).

Task

All participants reported to the University sports science laboratory for testing wearing shorts and a t-shirt. All measurements were recorded by the same clinician to avoid intertester variability. Warm up consisted of 5 minutes on a bicycle ergometer (Wattbike Cycle Ergometer, Wattbike Pro, Nottingham, UK) at a cadence of 60 RPM. Intensity was self-selected at what they felt was their normal warm up pace. Performance of the Y-balance test was conducted prior to isokinetic testing of hip abductor strength. The non-dominant limb (stance leg when kicking a ball) was used in both cases.

To perform the Y-balance test, participants were required to move each of the indicators in the anterior, posteromedial and posterolateral directions as far as possible, using the dominant foot. Isokinetic hip abductor strength was assessed in the side lying position (Figure 2).

Procedures

Participants had their limb length measured from the anterior superior iliac spine to the distal tip of the medial malleolus using an anthropometric tape measure. The YBT was described as a test of balance to participants. A member of the research team demonstrated the test before instructing the participant. Participants were asked to place the foot of the non-dominant leg (support leg when kicking a ball; used for standardization) on the stance block with the hallux perpendicular to the red line and with the dominant leg in contact with the ground for support prior to testing. Participants were then asked to move each of the indicators in the anterior, posteromedial and posterolateral directions as far as possible, using the dominant foot and without losing contact with the indicators. Participants returned to the starting position prior to completing each movement. Any loss of balance or repetitive movement was excluded and a new trial performed. Four trial attempts were carried out, to exclude any learning effect, prior to three test attempts as in Munro et al.[22]. The highest attempt in each direction was accepted as a value for anterior, postero-medial and posterolateral reach directions. Participants performed each trial when they were ready after the previous trial and without a defined rest period.

After completion of the YBT, participants had the non-dominant limb assessed for peak concentric torque of the hip abductors. The contraction speed (30°/s) was chosen due to the descending force associated with increasing speed of contraction.[26] Participants were side lying with a seat angle of 0°. The hip and knee of the dominant limb were flexed to 90°. The pelvis was in neutral to try to ensure the head of the femur of the non-dominant limb was aligned over that of the dominant limb. From this position and with the use of a goniometer the non-dominant hip (hip to be tested) was placed into 10° of extension in order to best isolate the hip abductors and limit torque generation from anterior muscles such as the quadriceps femoris muscle group, the iliopsoas and tensor fasciae latae.[27] This decision was made after it became noticeable during pilot testing that the hip of the leg being tested, when started in 0º, tended to move forwards. Beginning in 10º of hip extension meant the hip did not move past 0º during hip abduction. To secure this position, a velcro strap was fastened from either side of the seat above the iliac crest of the participant. As in Gordon et al.[28], a circular cushion was inserted under and parallel to the non-dominant limb to allow the limb to rest between contractions and also to reduce potential for over-activity in the adductor muscles. The dynamometer rotational axis was aligned with the greater trochanter (hip joint axis of rotation). The pad, into which participants exerted force into was placed 5cm above the base of the patella along the iliotibial band as in De Marche Baldon et al.[21]. Once secured, the mass of the limb was weighed in order to perform a gravitational correction. After familiarization with procedures, participants were given three trial attempts in which they were asked to perform at 25%, 50% and 75% of their perceived maximum as in Lepley et al.[29]. This was to ensure adequate warm up and reduce the potential for a learning effect[17] due to unfamiliarity with exerting force in a side lying position. A minimum of 3 and a maximum of 5 MVC's were undertaken by participants in order to ensure repeated measures within a coefficient of variance (CV) of 5%. If after 3 attempts there was not 2 contractions which satisfied the criteria (see below) for MVC and resided within a CV of 5%, a 4th trial was performed and if necessary a 5th. All participants generated repeated measures within 5 trials. Each contraction was separated by two minutes of stationary rest in order to ensure sufficient replenishment of the phosphor-creatine energy system.[30] The participant was instructed to consistently produce their maximal force rapidly, through their maximum range of motion (ROM) (as hard and as fast as possible in the frontal plane) and to maintain that force for 3-4 seconds. Participants received a 5 second count down with a distinct emphasis on "Go". No overt verbal encouragement was provided due to the difficulty in standardizing it for all participants.[31] Attempts not sustained for MVC (identified by an impact spike), containing an initial countermovement (identified by a visible drop/rise in the torque signal) >5 N·m or with a non-linear time-torque trace (identified by a double movement) were disqualified and excluded from further analysis. The remaining measures, which met the above criteria for a MVC and had repeated measures of peak torque within a CV of 5%, were accepted for correlation analysis with those of the YBT.

Statistical Analyses

Statistical analyses were performed using IBM SPSS statistics 22 for windows (SPSS, Inc., Chicago, IL). YBT test scores normalised for leg length were calculated as: (reach distance (cm)/leg length (cm)) *100. A Shapiro-wilk test was used to assess whether parameters for single leg dynamic balance and hip abductor strength were normally distributed. Mean, standard deviation (SD) and ranges are reported. The predictor variable (peak concentric torque) and criterion variable (anterior, poster lateral and posteromedial reaches) were normally distributed and therefore a Pearson's correlation analysis was used to assess the strength of the associations. The strength of association and 95% confidence intervals were classified based on that most recently suggested by the British Medical Journal: 0-0.19 very weak, 0.2-0.39, weak, 0.40-0.59 moderate, 0.6-0.79 as strong and 0.8-1 very strong. Simple linear regression analysis was used to quantify the variance in reach distance (normalized for limb length) explained by concentric peak torque (normalized for body mass). YBT distance (anterior, posterior-lateral or posterior-medial) was entered as the criterion variable and concentric hip abductor torque was entered as the predictor variable. Significance (2-tailed) was set at $P<0.05$ for all analyses.

Results

Participant limb length, concentric peak torque and YBT reach distances are displayed in Table 1. Concentric hip abductor peak torque was moderately correlated with all reach distances ($P<0.05$; Table 2). The posterior reach scores (normalized for limb length) of the YBT had the greatest association with peak concentric torque of the hip abductors (normalized for body mass). The posterolateral direction had the strongest association ($r=0.657$, $P<0.001$) with concentric peak torque, followed by the posteromedial ($r=0.574$, $P<0.001$) and anterior ($r=0.402$, $P=0.006$) direction respectively (Table 2). Hip abductor torque corrected for body mass explained 43% of the variance in posterolateral reach distance corrected for limb length (Table 2; Figure 3).

Discussion

This study sought to investigate the relationship between concentric hip strength torque and components (anterior, posteromedial, posterolateral) of the YBT. All balance components had a moderate association with concentric hip abductor strength and in accordance with our hypothesis were greater in the posteromedial and posterolateral directions compared to the anterior direction. Compared to the anterior reach, performance of the posterior reaches require a greater degree of hip flexion on the side of the stance leg.[32] This movement pattern is accomplished to a large extent by an anterior movement of the pelvis, a motion which requires greater eccentric hip muscle torque.[8]

The anterior reach of the YBT tends to cause participants to assume a more errect trunk posture which requires less hip flexion, and subsequently less anterior movement of the pelvis.[32] It is possible that this alteration in movement strategy requires participants to rely more on knee extensor muscle performance to accomplish the anterior reach task. This may explain the weaker association between hip abductor strength and anterior reach performance relative to the posterior reaches in the current study. These differences are likely due to the test constraints which require the foot to be extended out in front of the body during the anterior reach. Without a more upright posture, as the leg moves further forward there is a greater risk of loss of balance due to the centre of mass moving further away from its base of support. If the aim of the test was not to reach as far forward as possible, then a single leg squat (with the leg out in front) may be performed with a similar contribution from the hip extensors and abductors. Hubbard et al.[12] reported similar associations between isometric hip abduction, as measured by handheld dynamometry and posteromedial (r=0.51, *P*=0.004) and posterolateral (r=0.49, *P*=0.006) reach distances in thirty participants with chronic ankle instability (CAI). The slightly stronger associations in our study are perhaps due to the use of participants without CAI. Dynamic single limb stability is reportedly lower in patients suffering with CAI.[1] As healthy active young adults were observed in this study, direct comparison of results between cohorts cannot be made. Furthermore, peak torque has been shown to be angle specific,[26] meaning isometric assessment may not identify maximum strength in all participants.[33] This study utilised a predefined criteria for accepting a MVC as valid prior to accepting a measure of peak torque. Subsequently, only repeated measures which met this criteria and were within a CV of 5% were used for analysis. In addition, our protocol began with participants in 10º of hip extension to avoid the hip joint moving past 0º during side lying hip abduction which appeared to happen during pilot testing. These differences in protocol may give our measures greater criterion validity,[27] although as of yet, it is unknown whether there is a difference in torque output between test positions used in the literature.

The importance of the hip abductor muscles in facilitating single leg stability is perhaps underscored by the fact that concentric hip abductor strength explained 43% of the variance in the posterolateral reach direction. It may be that a semi-static balance test in which the base of support is fixed depends more on absolute strength than more dynamic balance tasks in which neuromuscular control may play a greater role. Furthermore, the moment arm of the proximal gluteal muscles is longer than the other distal lower extremity muscles that act directly on the ankle joint and as such, may be better at controlling the centre of mass during the lowering phase of the YBT. This suggestion is supported by Miller and Bird[34] who reported fatigue of the muscles of the hip and knee to have greater negative impact on single leg stability relative to fatigue of distal lower extremity muscles. More recently, Gribble and Hertel[35,36] demonstrated greater postural control deficits when fatiguing the hip abductors and adductors compared to the ankle invertors and evertors. The muscles acting on the hip and knee have a greater cross-sectional area and therefore greater force output than those at the ankle. Conversely, larger muscles may have less ability to rapidly adjust to perturbations in comparison to the smaller muscles around the ankle. It may be that that slower movement strategy allowed in the YBT, in addition to the repeated practice trials undertaken before a measurement is taken, does not require rapid adjustment from the ankle musculature but instead depends on the torque of the muscles acting on the hip and knee.

Limitations

Although the discussion of our data is plausible, it should be interpreted cognisant that although the association between hip strength and the posterior reaches is considered moderate to strong; the lower bound of the 95% confidence interval suggests the association may only be weak to moderate (Table 2). This study investigated a convenience sample of healthy active adults (18-35 years) and therefore sheds some light on the relationship between concentric hip strength and single leg stability but is not generalizable to all active populations. In addition, we did not control for previous history of concussion and cannot be sure that minor respiratory tract infections were not present which could affect the outcome of the balance tests.

Clinical Implications

Dynamic single leg stability is influenced by a multitude of factors including flexibility, neuromuscular control and strength. These data suggest that hip abductor strength may be an important contributor to single leg stability, particularly over a fixed base of support. Our findings, acknowledging the limitation of the cross-sectional study design, suggest that clinicians who wish to assess changes in single-leg balance, using the YBT, as a result of change in side-lying hip strength should focus on the posterior reaches.

Future Research

The authors implemented several measures to maximize the criterion validity of the hip abductor strength measures. However, this protocol of assessment can only be deemed more valid by a study design which compares muscle activity from this protocol to those in existing literature. Furthermore, the authors in the present study decided to use concentric hip abduction, a movement used to assess hip abductor strength and prescribed as a rehabilitation exercise in clinical practice, when performance of the YBT depends primarily on isometric and eccentric control of the hip abductors. Future research should attempt to describe the association between eccentric hip abductor strength and performance of the YBT to add to those who have used isometric strength and the concentric measures described in this study. Future research should also aim to quantify muscle activation for each of the YBT reach directions to enable better understanding of the muscular demands of the test. Finally, future research should screen for previous history of concussion.

Conclusion

The data presented in this study suggest that concentric hip abductor strength is moderately associated with dynamic single leg stability when measured using the YBT. In contrast to the anterior reach, the associations between strength and balance are greater when using the posterior reaches of the YBT.

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