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Research article

Isometric gluteus medius muscle torque and frontal plane pelvic motion during running

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Abstract
The objective of this study was to investigate the relationship between isometric GM torque and the degree of frontal plane pelvic drop during running. Twenty-one healthy, recreational runners (9 males, 12 females) who ran 8.05 km or more per week were obtained from a sample of convenience. GM maximal isometric torque was collected prior to the run. Subjects then ran on a treadmill for 30 minutes while bilateral three-dimensional pelvic kinematic data were collected for 10 seconds at each 2 minute increment. Left side pelvic drop showed a slight increase (effect size = 0.61); while, the right side pelvic drop remained stable (effect size = 0.18). Pearson's Correlations showed no relationship between GM isometric torque and frontal plane pelvic drop for any of the data collection periods during the 30-minute run. These results suggest that isometric GM torque was a poor predictor of frontal plane pelvic drop. One should question whether a dynamic rather than static measure of GM strength would be more appropriate. Future research is needed to identify dynamic strength measures that would better predict biomechanical components of running gait.

Key words: Strength, kinematics, Trendelenburg, hip.

Introduction

Running is becoming an increasingly popular fitness activity, with an estimated 30 million Americans classified as recreational runners (Austin, 2002). Meanwhile, the combination of repetitive loading and the increasing number of runners contributes to running-related injuries. In a systematic review by van Gent et al. (2007) the overall incidence rate of lower extremity running injuries was between 19.4% and 79.3%. The majority of musculoskeletal running injuries can be classified as overuse in nature, and can be traced to training errors, or anatomical or biomechanical factors (Hreljac et al., 2000; James et al., 1978; Macera et al., 1989).

The stance phase of running is a closed kinetic chain activity, during which proximal stability is needed to control the absorption of contact forces. If proximal instability exists, the body may become biomechanically disadvantaged in absorbing contact forces, which in turn could place the runner at an increased risk for lower extremity injury (Ferber et al., 2002; Marti et al., 1988). Ferber et al. (2002) found that females who had a history of lower extremity stress fracture exhibited greater peak impact vertical ground reaction forces (vGRF), loading rates, and peak tibial acceleration. Similar results were reported by Hreljac et al. (2000) in a group of male and female runners who sustained at least one overuse injury attributed to running. Ferber et al. (2003) additionally studied gender differences between kinetic and kinematic data for twenty male and female recreational runners. In the frontal plane of stance phase, females had a significantly greater peak hip adduction angle, hip frontal plane negative work, and peak hip adduction velocity as compared to males.

Core stability, as described in part previously by Frederiscon et al. (2005), Kibler et al. (2006) , Leetun et al. (2004), and Willson et al. (2005), could be defined as the lumbo-pelvic hip muscle strength and endurance yielding a coordinated activation of muscles and maintenance of alignment throughout the kinetic chain. When core instability exists, due to strength and/or endurance deficits, the body may not be optimally aligned. Frontal plane pelvic drop is one sign of core instability that could be identified as a weak link in the running kinetic chain. Pelvic drop in the frontal plane is named based on the stance leg and occurs when there is a downward obliquity, or Trendelenburg sign, of the opposite hip relative to horizontal during its swing phase (see Figure 1).

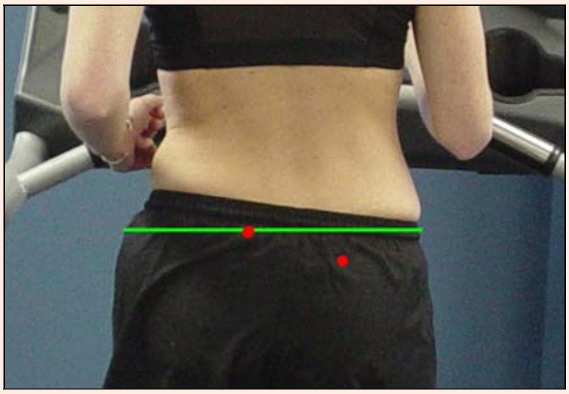

Figure 1. Example of left frontal plane pelvic drop. The runner is in left stance phase, and the pelvis is rotating in the frontal plane about the left hip, such that the right PSIS has dropped below horizontal.

Electromyography has shown that the gluteus medius muscle (GM), and to some extent the tensor fascia, are active during the stance phase of running, corresponding to a hip abduction moment (Mann et al., 1986). At foot-strike, these muscles eccentrically contract to control hip adduction, and then concentrically contract from the support phase into propulsion to create hip abduction (Mann et al., 1986). Because running occurs primarily in a sagittal direction, muscles associated with the frontal

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and/or transverse planes could in theory become weakened without cross training or strengthening. GM weakness, specifically, has been linked to running-related injury (Cichanowski et al., 2007; Fredericson et al., 2000; Leetun et al., 2004; Niemuth et al., 2005). These findings suggest that strength imbalances may be associated with or predispose an athlete to injury, or injuries may lead to strength imbalances.

Weakness in the hip musculature, especially the abductors, may impair efficient transference of forces, increase thigh adduction, and lead to frontal plane pelvic drop (Mann et al., 1986). Without compensation, an increased frontal plane pelvic drop could create a mechanically unstable system, which could result in an increased vGRF. Therefore, attempts to reduce frontal plane pelvic drop via GM strengthening are often included in gait retraining protocols (Presswood et al., 2008). However, there is a research void in the quantification of frontal plane pelvic drop and its association with static measures employed clinically. The purpose of this study was to investigate the relationship between pelvic drop during running and isometric GM torque. It was hypothesized that there would be a negative association between GM isometric torque and pelvic drop; subjects with less GM isometric torque would have increased pelvic drop associated with that side.

Methods

Twenty-one subjects (9 males, 12 females) (age 25.2 ± 3.8 years, height 1.73 ± 1.0 m, weight 70.6 ± 12.3 kg, and average mileage per week 33.3 ± 18.7 km) were recruited. The authors recognize the limitations of a mixed gender sample; however the subjects were recruited from a sample of convenience. In accordance with the institutional review board, research method approval was obtained. Subjects first provided written consent and completed a self-report running questionnaire, which included average weekly mileage and running-related injuries in the past 6 months. Subjects were recreational runners who ran ≥ 8.05 km per week. Subjects were excluded if they had a history of cardiopulmonary problems, neuromuscular impairment preventing the subject from running safely, or physician's orders prohibiting running. None of the subjects had an injury causing a decrement in running performance at the time of data collection.

Subjects' body weight and thigh length were first obtained. With the subject supine, thigh length was measured as the distance from the greater trochanter to the lateral knee joint line. To test GM isometric strength, the subject was positioned in side-lying with a pillow between the knees to approximate 10º of hip abduction, and a strap stabilized the subject's trunk. A second strap around the plinth table secured the hand-held dynamometer (Lafayette Instruments, Lafayette, IN) to the thigh just proximal to the lateral knee joint line, to allow for an isometric contraction. This set-up has been previously reported as reliable (Bohannon, 1997; Cahalan et al., 1989; Jaramillo et al., 1994). Subjects were instructed to attempt to raise their leg upward with maximal effort for 5 seconds; this was repeated for 4 trials on each leg with a 15 second rest between trials (Ireland et al., 2003). To assess the reliability of the GM isometric force measurement, an ICC was performed on the three repetitions for each leg in the 21 subjects and shown to be 0.90, demonstrating good reliability.

Subjects wore their own running shoes during data collection. With the subject standing on the treadmill (Cateye EC-T220, Boulder, CO), kinematic sensors (Polhemus Fastrak®, Colchester, VT) were secured over bilateral posterior superior iliac spines (PSIS) using double-sided tape. Following static standing baseline data collection, and a 5-minute warm-up, subjects were asked to run for 30 minutes at a self-selected, maintenance speed (mean 10.74 ± 1.06 km/hr). As part of an additional experiment, metabolic data were collected in 10 subjects (5 males, 5 females) during the run; all subjects' volume of oxygen (VO_2) reached steady state.

Three-dimensional kinematic data on pelvic motion were sampled at a rate of 60 Hz using an electromagnetic kinematic tracking system (MotionMonitor™ version 7.0, Innovative Sports Training, Chicago, IL). Kinematic data were collected in 10-second increments every two minutes, beginning at time zero. There were therefore 16 data collection blocks. Previous data were collected in 5 subjects to assess the test-retest reliability of the pelvic drop measure. This yielded an ICC of 0.80 and a standard error of the mean of 0.36º, demonstrating the measure had good reliability with little variance attributed to error.

The isometric force recorded from the last three trials was converted to torque using thigh length as the moment arm, normalized for body weight, and the average of these trials for each leg calculated. Kinematic data processing was performed using custom software written in the MATLAB™ (Math Work Inc, version 7.1) programming language. Bilateral pelvic angles were calculated as the angle between left and right PSIS relative to a horizontal plane minus the average baseline angle, using the following equation:

$$L\,\mathrm{deg} = (\sin^{-1}\theta((Lz - Rz)/(\sqrt{((Lx - Rx)^2 + (Ly - Ry)^2 + (Lz - Rz)^2)}))) - BL$$

where:
Ldeg = left pelvic angle (degrees)
Lz, Lx, Ly = left side z, x, and y direction data (mm)
Rz, Rx, Ry = right side z, x, and y direction data (mm)
BL = baseline pelvic angle (degrees).

Thus the average magnitude of change in pelvic angle from baseline (left and right pelvic drop) was found for each 10-second data collection block.

A Pearson's Correlation was used to assess the relationship between the average GM isometric torque and pelvic drop at each data collection block. Using SPSS® version 14.0, statistical significance was defined as α = 0.05. Using start and end means, effect size was calculated to assess changes within either the left or right side, and between sides during the 30-minute run. Effect sizes were defined as small, d = 0.2; medium, d = 0.5, and large, d = 0.6 (Cohen, 1998).

Results

The average isometric GM torque was 125.67 ± 31.82 Nm and 130.09 ± 37.96 Nm for the left and right sides, respectively. Average pelvic drop across the 30-minute run was 10.9º ± 1.7º on the left, and 7.6º ± 1.2º on the right. Left side pelvic drop showed a slight increase across the run, from 9.5º ± 3.3º at minute zero to 11.9º ± 4.4º at minute 30 (effect size = 0.61). Whereas, the right side pelvic drop remained fairly constant, with a starting pelvic drop of 7.5º ± 2.8º and ending of 8.1º ± 3.6º (effect size = 0.18). When comparing minute 30 means for the left and right sides, the effect size was 0.95.

Table 1. Pearson's Correlations between pelvic drop and GM torque as a function of time.

	LEFT		RIGHT	
	R	p-value	R	p-value
Minute 0	-0.184	0.425	0.138	0.550
Minute 2	-0.079	0.734	0.141	0.542
Minute 4	-0.147	0.526	-0.059	0.801
Minute 6	-0.257	0.261	0.081	0.729
Minute 8	-0.105	0.652	0.053	0.818
Minute 10	-0.176	0.445	0.045	0.845
Minute 12	-0.140	0.546	0.047	0.839
Minute 14	-0.173	0.453	0.004	0.986
Minute 16	-0.114	0.624	-0.034	0.885
Minute 18	-0.222	0.334	0.022	0.925
Minute 20	-0.342	0.129	0.003	0.990
Minute 22	-0.216	0.347	0.026	0.912
Minute 24	-0.251	0.273	0.066	0.777
Minute 26	-0.201	0.382	-0.058	0.803
Minute 28	-0.254	0.266	-0.115	0.618
Minute 30	-0.226	0.324	-0.097	0.675

Pearson's Correlations showed no significant correlation on either the left or right side between frontal plane pelvic drop and GM isometric torque for any of the data collection periods during the 30-minute run (see Table 1). Using an average pelvic drop across the 30-minute run, the relationship between left and right pelvic drop and GM isometric torque resulted in little relationship between these variables, as shown in Figures 2 and 3. This was further supported by non-significant, poor correlations of R = -0.212 (p = 0.356) and R = 0.022 (p = 0.925) for the left and right sides, respectively.

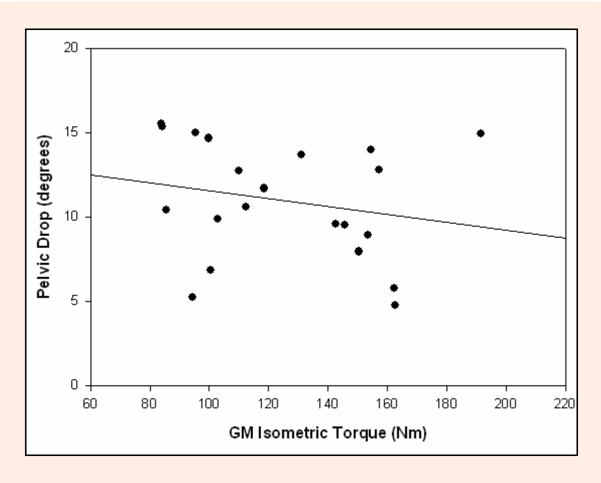

Figure 2. Left side pelvic drop versus GM isometric torque.

Since there was no correlation between GM isometric torque and either average pelvic drop or pelvic drop at each data collection point, the relationship between GM isometric torque and the rate of change (slope) of pelvic drop across the 30-minute run was also assessed. There was, however, no correlation or significant relationship on either the left (R = -0.182, p = 0.429) or right sides (R = -0.244, p = 0.287).

Post-hoc dependent t-tests were performed to assess for potential differences in the variables between genders. Pelvic drop showed no significant difference between genders for either the left (t = 0.331, p = 0.749) or right sides (t = -0.327, p = 0.752). Torque, however, did significantly differ between genders for both the left (t = -4.333, p = 0.003) and right sides (t = -5.005, p = 0.001). Due to the statistically significant difference between genders for GM torque, separate correlations were performed for males and females. Correlations between GM isometric torque and pelvic drop were still not significant for either males (R = -0.263, p = 0.494 and R = -0.147, p = 0.706) or females (R = -0.107, p = 0.741 and R = 0.051, p = 0.874) for the left and right sides, respectively.

Discussion

The objective of this study was to investigate the relationship between GM isometric torque and frontal plane pelvic drop in a sample of healthy, recreational runners who were instructed to run at a self-selected, comfortable pace for 30 minutes. The results indicate that GM isometric torque does not correlate well with pelvic drop in this sample. Thus, the hypothesis that pelvic drop would demonstrate an indirect relationship with isometric GM torque was not supported.

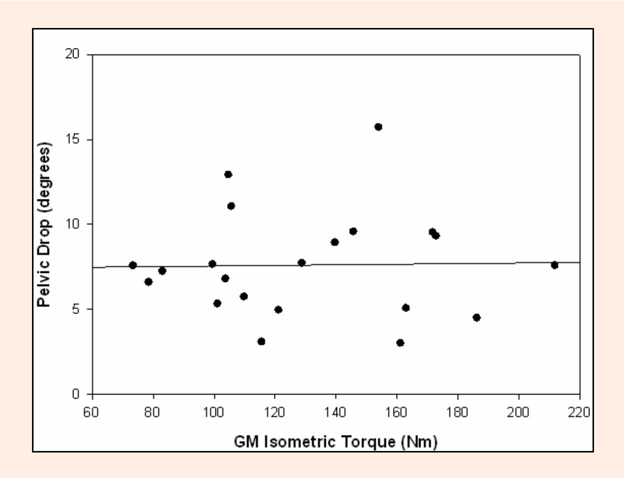

Figure 3. Right side pelvic drop versus GM isometric torque.

Although previous studies have not investigated frontal plane pelvic motion over extended periods of running, Schache et al. (2001) did study pelvic motion over 5-second increments during treadmill running. The 10 subjects' (9 males, 1 female) average pelvic drop was consistent with the pelvic drop values in the current study.

Prospective (Leetun et al., 2004), case-control (Fredericson et al., 2000; Ireland et al., 2003; Niemuth et al., 2005) and case-series (Cichanowski et al., 2007) studies have established an association between hip abduction isometric strength deficits and lower extremity injuries.

Additionally, Ferber et al. (2002) demonstrated an association between increased vGRF and lower extremity stress fractures in female runners. Although both decreased hip abduction isometric strength and increased vGRF are linked to lower extremity injuries, the relationship between decreased hip abduction static strength, increased vGRF, and/or frontal plane pelvic drop has not been established. Based on the current study, there was no relationship between static GM torque and frontal plane pelvic drop. However, limitations of the study could have impacted these findings.

A potential limitation of this study was the use of a mixed gender sample, as it was a sample of convenience. Possible differences in anthropometrics as well as strength could have affected the relationship between the variables. There was, however, no statistically significant difference between genders with regard to pelvic drop; although, GM torque did differ significantly between genders. Insignificant correlations between the variables remained even after correlations were run separately for each gender. Additionally, the sample consisted of healthy, recreational runners. Thus caution should be taken when attempting to apply these findings to either an injured or elite running population.

Subjects were instructed to run at a comfortable, constant pace for 30 minutes. The decision to have subjects self-select their speed was based on previous studies, to include Franz et al. (2009) and Schache et al. (2001). However, it is possible that subjects consciously or unconsciously selected an inadequate pace or modified their running gait during the run, thus impacting or altering the pelvic drop measure. Unfortunately, it is not plausible to tease out to which subjects this applied.

While the use of hand-held dynamometry and a make test have limitations, to include tester strength and subject participation, effort was made to minimize these effects. The use of a strap to secure the dynamometer eliminated the effect of tester strength, which has previously been shown to be limitation of hand-held dynamometry (Bohannon, 1999). A practice trial and recovery time between trials avoided error due to subject effort, and consistent directions during testing limited the influence of tester feedback. Only one tester performed the measurement and demonstrated good intratester, intrasession reliability. Additionally, the conversion of force measurements to torque allowed comparison across subjects by normalizing for body weight and thigh length.

Two questions should therefore be posed: 1. Is a static measure of GM strength appropriate to relate to dynamic measures?, and 2. Is there a more robust measure or group of variables that would correlate with pelvic drop.

Based on the research findings, one should question whether a dynamic rather than static measure of GM strength would be more appropriate. Clinically, qualitative observations during running gait analysis are typically linked to quantitative static strength assessments secondary to a lack of costly evaluative equipment or time. These findings suggest that this strategy is not appropriate for hip abduction. It is also plausible that factors other than GM strength, such as GM activation patterns or GM endurance affect frontal plane pelvic drop.

Future research is therefore needed to both investigate the relationship between GM torque, activation patterns, and muscle fatigue while running and pelvic drop, and to identify clinical dynamic strength measures that best predict biomechanical components of running gait. Clinicians may then better understand which aspects of the GM impact frontal plane pelvic drop in runners.

Conclusion

This research aimed to investigate the link between GM isometric strength and pelvic drop; however, isometric GM strength was a poor predictor of frontal plane pelvic drop. Future research studies should be aimed at investigating the relationship between dynamic measures, such as GM torque while running, clinical-based dynamic GM strength measures, GM activity and fatigue, and pelvic drop.

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References

Austin, W.M. (2002) Chiropratic health for recreational runners. *Journal of the American Chiropratic Association* **39,** 32-37.

Bohannon, R.W. (1997) Reference values for extremity muscle strength obtained by hand-held dynamometry from adults aged 20 to 79 years. *Archives of Physical Medicine and Rehabilitation* **78,** 26-32.

Bohannon, R.W. (1999) Intertester reliability of hand-held dynamometry: a concise summary of published research. *Perceptual and Motor Skills* **88,** 899-902.

Cahalan, T.D., Johnson, M.E., Liu, S. and Chao, E.Y. (1989) Quantitative measurements of hip strength in different age groups. *Clinical Orthopaedics and Related Research* **246,** 136-145.

Cichanowski, H.R., Schmitt, J.S., Johnson, R.J. and Niemuth, P.E. (2007) Hip strength in collegiate female athletes with patellofemoral pain. *Medicine & Science in Sports & Exercise* **39,** 1227-1232.

Cohen, J. (1998) *Statistical power analysis for the behavioral sciences*. 2nd edition, Lawrence Earlbaum Associates, New Jersey.

Ferber, R., Davis, I.M., Hamill, J., Pollard, C.D. and McKeown, K.A. (2002) Kinetic variables in subjets with previous lower extremity stress fractures. *Medicine & Science in Sports & Exercise* **34,** S5.

Ferber, R., Davis, I.M. and Williams, D.S. (2003) Gender differences in lower extremity mechanics during running. *Clinical Biomechanics* **18,** 350-357.

Franz, J.R., Paylo, K.W., Dicharry, J., Riley, P.O. and Kerrigan, D.C. (2009) Changes in the coordination of hip and pelvis kinematics with mode of locomotion. *Gait & Posture* **29,** 494-498.

Fredericson, M., Cookingham, C.L., Chaudhari, A.M., Dowdell, B.C., Oestreicher, N. and Sahrmann, S.A. (2000) Hip abductor weakness in distance runners with iliotibial band syndrome. *Clinical Journal of Sports Medicine* **10,** 169-175.

Fredericson, M. and Moore, T. (2005) Muscular balance, core stability, and injury prevention for middle- and long-distance runners. *Physical Medicine and Rehabilitation Clinics of North America* **16,** 669-689.

Hreljac, A., Marshall, R.N. and Hume, P.A. (2000) Evaluation of lower extremity overuse injury potential in runners. *Medicine & Science in Sports & Exercise* **32,** 1635-1641.

Ireland, M.L., Willson, J.D., Ballantyne, B.T., and Davis, I.M. (2003) Hip strength in females with and without patellofemoral pain. *Journal of Orthopaedic & Sports Physical Therapy* **33,** 671-676.

James, S.L., Bates, B.T. and Osternig, L.R. (1978) Injuries to runners. *American Journal of Sports Medicine* **6,** 40-49.

Jaramillo, J., Worrell, T.W. and Ingersoll, C.D. (1994) Hip isometric strength following knee surgery. *Journal of Orthopaedic & Sports Physical Therapy* **20,** 160-165.

Kibler, W.B., Press, J. and Sciascia, A. (2006) The role of core stability in athletic function. *Sports Medicine* **36,** 189-198.

Leetun, D.T., Ireland, M.L., Willson, J.D., Ballantyne, B.T. and Davis, I.M. (2004) Core stability measures as risk factors for lower extremity injury in athletes. *Medicine & Science in Sports & Exercise* **36,** 926-934.

Macera, C.A., Pate, R.R., Powell, K.E., Jackson, K.L., Kendrick, J.S. and Craven, T.E. (1989) Predicting lower-extremity injuries among habitual runners. *Archives of Internal Medicine* **149,** 2565-2568.

Mann, R.A., Moran, G.T. and Dougherty, S.E. (1986) Comparative electromyography of the lower extremity in jogging, running, and sprinting. *American Journal of Sports Medicine* **14,** 501-509.

Marti, B., Vader, J.P., Minder, C.E. and Abelin, T. (1988) On the epidemiology of running injuries: the 1984 Bern Grand-Prix study. *American Journal of Sports Medicine* **16,** 285-293.

Niemuth, P.E., Johnson, R.J., Myers, M.J. and Thieman, T.J. (2005) Hip muscle weakness and overuse injuries in recreational runners. *Clinical Journal of Sports Medicine* **15,** 14-21.

Presswood, L., Cronin, J., Keogh, J. and Whatman, C. (2008) Gluteus medius: applied anatomy, dysfunction, assessment and progrssive strengthening. *Strength and Conditioning Journal* **30,** 41-53.

Schache, A.G., Blanch, P.D., Rath, D.A., Wrigley, T.V., Starr, R. and Bennell, K.L. (2001) A comparison of overground and treadmill running for measuring the three-dimensional kinematics of the lumbo-pelvic-hip complex. *Clinical Biomechanics* **16,** 667-680.

van Gent, R.N., Siem, D., van Os, A.G., Bierma-Zeinstra, S.M. and Koes, B.W. (2007) Incidence and determinants of lower extremity running injuries in long distance runners: A systematic review. *British Journal of Sports Medicine* **41,** 469-480.

Willson, J.D., Dougherty, C.P., Ireland, M.L. and Davis, I.M. (2005) Core stability and its relationship to lower extremity function and injury. *Journal of the American Academy of Orthopaedic Surgeons* **13,** 316-325.

Key points

- There is a lack of research linking static, clinical measures to dynamic running gait observations.
- Isometric gluteus medius muscle torque is a poor predictor of frontal plane pelvic drop in running.
- Future studies should identify dynamic strength measures that correlate with elements of running biomechanics.

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