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Gluteal muscle function and size in swimmers

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ABSTRACT

Objectives: To compare the gluteus medius and minimus segments size and activity in swimmers versus non-swimmers.
Design: Case matched-control cross-sectional study.
Methods: The three segments of gluteus medius (anterior, middle and posterior) and two segments of gluteus minimus (anterior and posterior) were evaluated using electromyography and magnetic resonance imaging in 15 swimmers (7 elite and 8 non-elite) and 15 gender- and aged-matched controls. For each muscle segment, values were obtained for peak amplitude, average amplitude, and time to peak from each phase of the gait cycle (0–20%, 20–60%, and total stance).
Results: The pattern of anterior gluteus minimus EMG activity in swimmers demonstrated additional activity early in the gait cycle when compared with controls. The segmental differences between anterior and posterior gluteus minimus during gait identified in the control group were not present in the swimmers. Overall, there were no significant differences in the gluteus medius EMG characteristics between groups and muscle size was not significantly different between groups for any of the hip abductor muscles.
Conclusions: The preliminary evidence of non-segmental differences within the gluteus minimus of swimmers (as opposed to non-swimmers) might implicate reduced-gravity environments in contributing to subsequent changes in deep stabiliser muscles. Such changes might predispose the athlete to a greater risk of lower limb injury during weight bearing activities.

1. Introduction

Swimming is one of the highest participation sports and recreational physical activities among Australians,[1] with well documented benefits for health.[2] Despite these benefits, for those competing at high levels, the chronic exposure to a buoyant, non-weight bearing (WB) environment is thought to be responsible for the development of deloading-related adverse consequences on postural support mechanisms, perhaps explaining a swimmer's susceptibility to injury during dry-land cross-training tasks.[3,4] A better understanding of postural WB muscle function during locomotion in this population is required to shed light on the potential mal-adaptive consequences of participating in a non-WB sport.

The gluteal muscles are considered key muscles for maintaining pelvic stability, hip stability, upright posture and locomotion. Gluteus minimus (GMin) is a deep hip joint stabiliser because of its morphological orientation and approximation to the hip joint capsule;[5] and is reported to have higher numbers of muscle spindles,[6] and a higher proportion of Type 1 muscle fibres than its hip abductor synergists.[7] These local stabilising properties suggest that GMin may be more vulnerable than gluteus medius (GMed) to adverse changes in size or function in response to a lack of gravitational load,[8] as in swimming. Dysfunction of GMin may affect the ability to bear weight during functional tasks such as walking.

The primary aim of this study was therefore to compare GMin and GMed muscle size (MRI) and activity (electromyography, EMG) in swimmers to a healthy age- and gender-matched sample. EMG has been used in 'non-swimming' healthy adults during gait to demonstrate that the components of GMin (anterior and posterior) and GMed (anterior, middle and posterior) are functionally unique,[9,10] being active at different times and intensities during walking. It was therefore the secondary aim of this study to identify whether the segmental EMG differences identified in 'non-swimmers'[9,10] during gait are also present in swimmers.

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Knowledge of potential adverse adaptations in these muscles may have implications for the development of injury prevention strategies in swimmers and other deloading sports, hobbies, occupations or environments.

2. Methods

A convenience sample of 15 adult swimmers and 15 age- and gender-matched control participants were recruited between the periods of November 2010 and February 2012 for this cross-sectional study. This sample size was based on a previous cross-sectional study with a harmonic mean sample size of 8 that detected a large difference in GMed muscle size (effect size of 0.74) between people with osteoarthritis (6 participants with advanced pathology, and 6 participants with mild pathology) and matched controls (12 participants).[11] A sample of 15 per group was used in this study to detect a difference in muscle size of similar magnitude. Swimmers were recruited from local swim clubs in Melbourne, Australia. Swimmers were required to be active in swimming on a weekly basis for the last 8 years,[12] and were retrospectively dichotomised into elite (current National or International competitive swimmers) or non-elite (current State level competition or lower) to facilitate comparisons of homogeneous groups. Control participants were required to be active >2 h of sweat-inducing activity/week; satisfy a Tegner Activity Score >3,[13] and were excluded if they were exposed to ≥1 session of aquatic exercise/week. Potential participants were excluded if they had hip or lumbar spine pain requiring management in the last three months; conditions that excluded them from MRI investigation or were >30 years of age (to reduce the potential of age-related musculoskeletal conditions). This study was approved by the University Human Ethics Committee (UHEC 10-065) and all participants gave written informed consent.

General demographic details including age, height, weight and gender were recorded at the beginning of the trial. Past and current physical activity with respect to WB activity was assessed using the Bone Specific Physical Activity Questionnaire (BPAQ).[14] All testing was performed on the stance dominant limb.[15]

Measurement of hip abductor muscle size was performed with a 1.5-T MR scanner (Magnetom Espree, Siemens Medical Solutions, Erlangen, Germany) using Spinal Array elements and two 8-channel Body Matrix Coils. Axial T1 weighted sequences (slice thickness, 6 mm; inter-slice gap, 0 mm) were acquired from above the iliac crest to just below the distal aspect of the tensor fascia lata (TFL) in supine participants. All hip abductor muscles, including the GMed, GMin, TFL and upper gluteus maximus (GMax) were included.[11] De-identified images were stored on a CD for offline processing, where the fascial border of each muscle was traced manually in each axial slice using Sante DICOM Editor software (Santesoft, Athens, Greece). The cross-sectional area of each muscle was summed, and multiplied by the slice thickness to generate a muscle volume estimate ($ICC_{2,1}$ = 0.87–0.99).[11]

Muscle activity was measured with bipolar fine-wire intramuscular EMG electrodes inserted with the aid of real-time ultrasound imaging into GMed (anterior, middle and posterior) and GMin (anterior and posterior) using a verified protocol.[16,17] Footswitches were used to record temporal aspects of the gait cycle.[10] A Delsys® Bagnoli-16 EMG system (Delsys Inc., Boston, USA) recorded the raw signal from the footswitches and intramuscular electrodes.

Participants were guided through a series of walking trials and maximum voluntary isometric contractions (MVICs).[9,10] For gait trials, participants walked barefoot, at a self-selected, comfortable walking speed along a 9 m walkway. This was repeated 6 times, with the final 4 trials recorded for analysis. Trials were repeated if they exceeded ±5% of their average walking speed (established during warm-up trials). This was followed by MVICs across five different hip actions,[9,10] for the purpose of amplitude normalising EMG data.

EMG processing and data pertaining to the control group have been reported previously, and were used for comparisons to the swimming groups in this study.[9,10] Briefly, a grand ensemble curve was generated for each segment across the gait cycle that was time normalised to 100 points and amplitude normalised to %MVIC. Previous analysis of control group data identified a biphasic pattern of activity in the stance phase of the gait cycle, so data were acquired from 3 phases of the gait cycle: 0–20% (early stance, first burst of activity), 20–60% (mid to late stance, second burst of activity) and total stance (heel strike to toe-off).

Delsys EMGworks 4.0 signal analysis software was used to acquire the dependant variables from the linear envelopes of each participant's trials. For each muscle segment, values were obtained for peak amplitude (%MVIC), average amplitude (%MVIC) and time to peak (TTP, % of gait cycle) from each phase of the gait cycle (0–20%, 20–60%, and total stance).

Participant characteristics including, age, height, weight, gender and loading status were compared between groups using Fishers exact tests (ratio comparisons), ANOVAs (parametric) or Kruskal–Wallis tests (K–W) (non-parametric). All EMG and MRI data were de-identified to ensure the data analyst was blind to participant group.

Due to violations of normality assumptions, K–W tests were used to compare muscle volume between the three groups (control participants, non-elite swimmers and elite swimmers). Separate K–W tests were performed for each muscle using an alpha of 0.05. Bonferroni adjusted Mann–Whitney *U* tests were used for post hoc comparisons ($\alpha = 0.017$).

Activity of the five muscle segments were analysed separately for each EMG variable. The ensemble curves were qualitatively described and compared between groups (number and location of bursts).[9,10] Quantitative differences in mean EMG activity between groups were determined with a one-way ANOVA. Where significant differences were present ($p < 0.05$), a Bonferroni-adjusted independent samples *t*-test was performed between all pairs of comparisons to determine where the differences existed ($\alpha = 0.017$).

Previously, a between-muscle segment comparison within the control sample revealed significant differences in recruitment between anterior and posterior GMin;[9] and between anterior and the remaining two GMed segments within the gait cycle.[10] These comparisons were also performed within each swim group (elite and non-elite) to determine if similar differences occurred within the muscles of swimmers. Independent samples *t*-tests (GMin anterior and posterior) and one-way ANOVAs (GMed anterior, middle and posterior) compared muscle activity between segments within each swimming group across all EMG gait variables ($\alpha = 0.05$). Post-hoc comparisons for GMed segments were performed with Bonferroni adjusted independent samples *t*-tests ($\alpha = 0.017$). To provide a measure of the magnitude of difference, a standardised mean difference (SMD; mean difference/pooled SD) was calculated for all segmental GMin comparisons and for all GMed post-hoc comparisons.[18]

3. Results

Eight swimmers were classified as non-elite and seven as elite. There were no significant differences between groups for any demographic variables, gender ratios, limb tested or land-based training hours (Table 1). Groups were significantly different in current BPAQ scores (Table 1), with control participants having higher scores than elite swimmers ($t_{14} = 4.159$, $p = 0.001$).