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Full Length Article

Relationship between postural control and muscle activity during a handstand in young and adult gymnasts

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ABSTRACT

The aim of this study was to evaluate the relationship between muscle activity and inter-muscle contributions patterns and postural control during a handstand. Additionally, outcomes were compared between young and adult gymnasts (mean ± SD: 13.9 ± 0.7 and 23 ± 3 years respectively). Participants performed three trials of a 10 s handstand on a force platform with simultaneous EMG signal recording at the upper and lower limbs. Adult gymnasts demonstrated significantly better postural control in each studied variable. The wrist flexors demonstrated the highest relative mean (60%) and peak (200%) EMG activity of all muscle groups studied. Wrist flexor activity was also highly correlated with postural control variables in both groups. The trapezius descendens and wrist flexor muscles demonstrated the highest contribution (20–26% and 25.5–28% respectively), followed by anterior deltoid (15–18%) and triceps brachii (13–16%) in both groups. The young gymnast group demonstrated significantly greater mean relative muscle activity at the triceps brachii, biceps brachii and rectus femoris compared with the adult group (88% ($p = 0.023$), 150% ($p = 0.003$) and 75% ($p = 0.039$) respectively). To conclude, despite comparable inter-muscle contributions during a handstand, young and adult gymnasts demonstrated a different relationship between muscle activity and postural control variables.

1. Introduction

An upright standing position is natural for human beings. It is learned during the early stages of development and allows individuals to perform upper limb tasks while walking (Bairstow & Laszlo, 1981; Winter, 1995). However, some individuals also develop the ability to stand on their upper limbs for the purposes of entertainment and sport.

An untrained person is incapable of maintaining steady, static balance during a handstand. It is a difficult task which requires a high degree of muscle strength and endurance to hold the full weight of the body as well as the cardiovascular endurance required to withstand the inverted position (Shvartz, 1968). A performer must also develop a great sense of balance to maintain a static position, an ability which depends on proprioceptive, vestibular and visual sensors (Gautier, Thouvarecq, & Chollet, 2007; Sobera, Siedlecka, Piestrak, Sojka-Krawiec, & Graczykowska, 2007). Maintaining balance in an inverted position is difficult due to: 1) the smaller base of

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support, 2) higher center of mass than in upright standing, and 3) the lesser strength of the wrist joints compared to the ankles (Gautier, Marin, Leroy, & Thouvarecq, 2009; Kerwin & Trewartha, 2001; Prassas, 1988). The ability to control the center of mass relative to the base of support is one of the aims of postural control, and requires the integration of vestibular, somatosensory and visual information (Horak & Macpherson, 2011; Massion, 1994).

Despite the fact that the upper limbs are not adapted to support bodyweight, upper limb kinematics during a handstand is similar to lower limb kinematics during upright standing (Slobounov & Newell, 1996). The wrist joints act similarly to the ankle joints, and the elbow and the shoulder joints act similarly to the knee and hip joints respectively (Gautier et al., 2007; Kerwin & Trewartha, 2001). The maintenance of balance is initially controlled by the wrists and then shoulder with hip strategies being adopted when postural sway becomes too great or in response to a perturbation (Kerwin & Trewartha, 2001; Yeadon & Trewartha, 2003).

Previous researches have investigated a number of aspects of postural control during a handstand including center of pressure (CoP) sway (Asseman, Caron, & Crémieux, 2004; Croix, Chollet, & Thouvarecq, 2010; Sobera et al., 2007), dynamics analysis (Gautier et al., 2009; Kerwin & Trewartha, 2001; Slobounov & Newell, 1996), ecological theory (Gautier et al., 2007), and limited electromyographic (EMG) analyses (Clement & Rezette, 1985; Yeadon, Rosamond, & Hiley, 2012). However, there is lack of extensive research regarding neuromuscular contribution during a handstand and its relationship to postural control in terms of posturography.

Although previous research has provided insight into how particular joints contribute to postural control during a handstand (Blenkinsop, Pain, & Hiley, 2017; Kerwin & Trewartha, 2001; Yeadon & Trewartha, 2003) these studies did not investigate the involvement of individual muscles. Investigation of postural sway during handstands has been primarily conducted using time-dependent analyses such as cross-correlation of EMG feedback time delays (Blenkinsop, Pain, & Hiley, 2016) and regression modelling of torque joint (Yeadon & Trewartha, 2003). As the ability to maintain the center of gravity in a stable position is dependent upon constant position correction via muscle activity (Borg, Finell, Hakala, & Herrala, 2007; Houdijk, Brown, & van Dieën, 2015), a correlation between the magnitude of muscle activity (amplitude) and postural control variables should be observed during a handstand. Muscle activity preventing the loss of balance briefly utilizes additional fast twitch fibers to enable a quick reaction (Daly, 2010; Johnson & Woollacott, 2011). Therefore, maximal CoP sway and displacement velocity should be more strongly correlated with peak EMG signal than with the mean value over a time period.

While previous research has found a correlation between wrist muscle activity and postural control during a handstand (Clement & Rezette, 1985), muscle activity at the elbow, shoulder and hip joints has not been investigated. The contributions of these muscle groups is likely to be important as, in comparison to upright standing, postural control of a handstand involves more than a single strategy at the wrist joint (Blenkinsop et al., 2016; Kerwin & Trewartha, 2001; Yeadon & Trewartha, 2003). It was hypothesized that muscle activity at the wrist would correlate with postural sway to a greater degree than activity at the elbow, shoulder and hip. It was also hypothesized that the wrist muscles would demonstrate the highest effort in maintaining balance, followed by shoulder girdle and arm muscles and hip muscles.

Gymnasts undergo continuously training from early years of their physical development (Kochanowicz & Kochanowicz, 2010; Kochanowicz, Kochanowicz, Niespodziński, Mieszkowski, & Biskup, 2015). They learn crucial gymnastic skills like the handstand and later master them so they can utilize them in other more difficult exercises or conditions (Hedbávný, Sklenaříková, Hupka, & Kalichová, 2013; Prassas, 1988). As a result, their ability to control balance during both upright stance and a handstand increases along with their experience and age (Asseman et al., 2004; Croix et al., 2010; Gautier, Thouvarecq, & Larue, 2008). Busquets, Marina, Davids, and Angulo-Barroso (2016) showed that gymnasts' movement pattern variability was dependent upon both training experience and physical development. It would therefore be expected that younger, less experienced gymnasts would demonstrate different neuromuscular control patterns (inter-muscle contribution) during a handstand than those with greater experience. However, differences in muscle activity between experts and non-experts have not been evaluated. It was hypothesized that younger gymnasts would exhibit higher relative muscle activity because of their higher effort and that they would rely to a greater degree upon supporting control strategies at the shoulders and hips.

Insight into the control of the muscles involved in maintaining a stable handstand by novice and expert athletes will assist in the assessment of skill-improvement and will improve our knowledge of what is necessary to master a handstand. Therefore, the aims of this study were: 1) to investigate the relationship between muscle activity and postural control during a handstand, and 2) to compare neuromuscular control patterns between children who have trained to perform handstands on a flat, stable surface, and elite adult gymnasts who are able to perform a handstand on gymnastics rings.

2. Methods

2.1. Participants

Fifteen young and eleven adult elite male gymnasts aged 13.9 ± 0.7 and 23 ± 3 years, respectively participated in the study. Participants' body mass and height was 45.2 ± 7.7 kg, 154.9 ± 9.8 cm and 72.1 ± 3.3 kg, 172.8 ± 4.3 cm for young and adult gymnasts respectively.

The criteria for participant inclusion were: a) all gymnasts started their training career at the age of six or seven; b) all participants trained for a minimum of 22 h a week; c) elite gymnasts were considered eligible if they were able to maintain a flawless handstand on the rings for five seconds. This study was conducted with the approval of the Bioethics Committee at the Regional Medical Chamber in Gdansk (approval number KG -12/15). All participants and children's legal guardians gave written informed consent prior to their participation.