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ORIGINAL RANDOMISED STUDY

Different weight bearing push-up plus exercises with and without isometric horizontal abduction in subjects with scapular winging: A randomized trial

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KEYWORDS
Push-up plus;
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Serratus anterior;
Weight-bearing

Summary The aim of the present study was to determine whether the application of isometric horizontal abduction (IHA) differentially affected two weight-bearing push-up plus exercises by examining activation of the scapulothoracic muscles in subjects with scapular winging. Fifteen male subjects performed standard push-up plus (SPP) and wall push-up plus (WPP), with and without IHA. Two-way analyses of variance using two within-subject factors were used to determine the statistical significance of observed differences in upper trapezius (UT), pectoralis major (PM), and serratus anterior (SA) muscle activities and UT/SA and PM/SA muscle activity ratios. UT and SA muscle activities were greater during SPP than WPP. PM muscle activity was lower with IHA application. The UT/SA and PM/SA muscle activity ratios were lower during SPP than WPP. The PM/SA muscle activity ratio was lower with IHA application. The results suggest that IHA application using a Thera-Band can effectively reduce PM muscle activity during SPP and WPP exercises. Moreover, the SPP exercise can be used to increase UT and SA muscle activity and reduce the UT/SA and PM/SA muscle activity ratios in subjects with scapular winging.

Abbreviations: IHA, Isometric horizontal abduction; SPP, standard push-up plus; WPP, wall push-up plus; UT, upper trapezius; PM, pectoralis major; SA, serratus anterior; RVC, reference voluntary contraction; CI, confidence interval; MCID, minimum clinically important difference.

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Introduction

The serratus anterior (SA) muscle is critical for balancing the rhythm of the scapulohumeral and scapulothoracic muscles located around the shoulder girdle (Dvir and Berme, 1978; Kamkar et al., 1993, Ludewig et al., 1996). The nature of the anatomical attachment of the SA allows the muscle to exert not only upward rotation of the scapula, but also linkage of the scapula to the thorax (Ekstrom eet al 2004, Kauppila and Vastamäki 1996, Neumann, 2002). Weakness, fatigue, or abnormal activation of the SA triggers shoulder dysfunction, including scapular winging, which could lead to scapular pain (Ludewig and Cook, 2000; Lukasiewicz et al., 1999; McClure et al., 2004). Thus, the SA requires particular attention in any shoulder rehabilitation program (Ludewig et al., 2004). Previous work has confirmed the utility of many SA-strengthening exercises (Ludewig and Cook, 2000; McClure et al., 2004; Decker et al., 1999; Ekstrom et al., 2003). However, it is not clear that all exercises recognized to strengthen the SA are appropriately focused on the recovery of the desired scapulohumeral and scapulothoracic rhythm.

Sahrmann (2002) made it clear that shoulder injuries and abnormal scapular motion are caused by an imbalance in the activities of various shoulder muscles rather than by any overall weakness of those muscles (Sahrmann, 2002). If shoulder dysfunction is caused by an imbalance among the activities of the scapulothoracic muscles (Escamilla and Andrews, 2009), therapeutic exercises should seek to increase activation of the SA and reduce the activity levels of compensatory muscles (Ludewig et al., 2004; Andersen et al., 2012; Huang et al., 2013). Imbalance among the scapulothoracic muscles should be monitored during SA-strengthening exercises via close observation of the actions of compensatory muscles including the upper trapezius (UT) and the pectoralis major (PM) (Farina et al., 2008). It has been suggested that over-activation of the UT contributes to the development of abnormal scapular motion (Ludewig and Cook, 2000; Ludewig et al., 2004; Sahrmann, 2002). Excessive recruitment of the UT compensates for SA weakness to restore scapular stability (Decker et al., 1999; Cools et al., 2007; Ludewig and Reynolds, 2009; Tucker et al., 2010). Additionally, high-level activation of the PM can substitute for SA activation (Decker et al., 1999; Park et al., 2013). It is thus important to minimize compensating actions during SA-strengthening exercises.

Moseley et al. (1992) recommended the use of the standard push-up plus (SPP) exercise to strengthen shoulder muscles, especially the SA (Moseley et al., 1992). Decker et al. (1999) reported that the SA exhibited the highest level of activation during the "plus" phase of the SPP exercise compared with numerous other rehabilitation exercises (Decker et al., 1999). Additionally, Ludewig et al. (2004) measured the ratio of UT to SA activity during modified push-up plus exercises on elbows, knees, and against a wall (Ludewig et al., 2004). The SPP exercise was optimal for training imbalanced muscles because SA muscle activity was increased maximally, and the UT/SA muscle activity ratio showed a maximum reduction. The wall push-up plus (WPP) exercise was recommended as an initial exercise for patients who could not perform the SPP exercise because the WPP exercise exerts relatively low muscle loads compared with other clinically used push-up plus exercises.

Previous reports have suggested the use of isometric horizontal abduction (IHA) to effectively reduce excessive PM muscle activity and to facilitate SA muscle activity selectively during three SA activation exercises (Park et al., 2013). To our knowledge, no reported study has yet compared the effect of IHA application (e.g., using a Thera-Band) on UT, PM, and SA muscle activities and UT/SA and PM/SA muscle activity ratios of two different weight-bearing push-up plus exercises (SPP vs. WPP) in subjects exhibiting scapular winging.

Thus, this study was performed to compare the effects of IHA application on UT, PM, and SA muscle activities and UT/SA and PM/SA muscle activity ratios between SPP and WPP in subjects with scapular winging. We hypothesized that there would be differences in muscle activities and muscle activity ratios with and without IHA application during the two weight-bearing push-up plus exercises.

Methods

Subjects

In total, 15 male subjects were recruited [age = 21.67 (20.44; 22.90) years, height = 1.77 (1.74; 1.80) m, weight = 68.29 (61.42; 75.10) kg, and body mass index = 21.98 (19.27; 24.69) kg/m^2]. A statistical power analysis using G*Power 3.1 (Faul et al., 2009) was performed after pilot testing in five subjects. According to the power analysis with the direct input of partial η^2 (0.2) from the result of pilot testing, it showed that seven subjects should be included to achieve a minimum power of 0.80 with a significant $\alpha < 0.05$ and an effect size of 0.50 (Other inputs included the number of group (1), the number of measurement (4), correlation among measurement (0.5), and non-sphericity correction ε (1).

Participants' shoulders were assessed to determine and quantify scapular winging. Scapular winging on the dominant side was identified with a scapulometer (interclass correlation coefficient: 0.97, 95% confidence interval (CI): 0.87–0.99, standard error of the measurement: 0.1 cm) and was considered present when the distance between the thoracic wall and the inferior angle of the scapula was $\geq$2 cm (Weon et al., 2011). The mean value for this distance in all subjects was 2.43 (2.15; 2.71) cm. Exclusion criteria were 1) having winged scapula due to a neurological problem, 2) any self-reported history of injury to or surgery of the shoulder or the upper extremities that might compromise performance of the push-up plus exercises, 3) inability to maintain a push-up posture for 5 min (all subjects were tested by sustaining push-up posture for 5 min prior to participation), and 4) involvement in sports at a competitive level or upper-limb strengthening exercise training for more than 5 h per week, and 5) $>$5 in visual analog score [mean VAS value of the subjects was 2.05 (0.73; 3.37)].

All subjects provided written informed consent after reading a detailed explanation of the experimental