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Original article

The importance of body mass normalisation for ultrasound measurement of the transversus abdominis muscle: The effect of age, gender and sport practice

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ABSTRACT

Background: Some studies have not considered body mass as a confounder in TrA analysis, which may have led to improper interpretation of results.
Objectives: To assess the differences in the effect of age, gender and physical activity between normalised for body mass and actual values of the TrA as well as to establish the effect of age, gender and physical activity on normalised for body mass TrA thickness in adolescents.
Design: The study was a cross-sectional study conducted at selected primary and secondary schools, and colleges in the Silesian region of Poland.
Method: A real-time ultrasound was used to obtain images of the TrA muscle. Body mass normalisation for TrA thickness was performed with allometric scaling and the following equation: Allometric-scaled TrA = TrA thickness/body mass$^{0.61}$.
Results: Analysis has shown that boys have significantly thicker muscle by 0.27 mm (95% CI 0.04–0.50) than girls, and those who practise sports have thicker muscle by 0.30 mm (95% CI 0.06–0.52) than non-active individuals. For allometric-scaled TrA, there were no significant effects ($p > 0.50$). There was a significant correlation between participants age and the actual value of the TrA ($r = 0.42$, $p < 0.05$). The correlation between age and allometric-scaled TrA was insignificant and close to zero ($r = -0.006$, $p = 0.93$).
Conclusions: An analysis of TrA thickness without body mass normalisation can deliver improper interpretation of study results. Thus, it is recommended in future researches to analyse TrA thickness measurement after normalisation rather than actual values. In the adolescent population, there is no effect of gender, age and physical activity on allometric-scaled TrA thickness.

1. Introduction

During the last few decades the role of the transversus abdominis muscle (TrA) in spine and pelvic stability has been confirmed (Richardson et al., 2002; Stokes et al., 2011; Gong, 2013). Attempts have been made to connect morphological changes in the TrA to different conditions, such as low back pain and scoliosis (Linek et al., 2015c, 2016a; Rostami et al., 2015b; Borna et al., 2016; Noormohammadpour et al., 2016). It was shown that patients with adolescent idiopathic scoliosis had thinner TrA muscle (Linek et al., 2016a). Such changes in TrA morphology reflect the muscle hypertrophy (Sanchis-Moysi et al., 2013) or atrophy (Kim et al., 2013; Belavý et al., 2016). To better understand TrA morphology (possible hypertrophy or atrophy), and also to identify potential confounders, the effects of age, gender, hand dominance and physical activity, as well as body mass and body height, have been investigated (Rankin et al., 2006; Springer et al., 2006; Mannion et al., 2008; Linek et al., 2015a, 2015d). Ultrasound imaging (US) is the most common tool, which allows reliable assessment of the TrA morphology in a variety of populations (Linek et al., 2014, 2015b; Wilson et al., 2016).

A number of studies have demonstrated that, regardless of the examined population, body mass is highly correlated with the thickness of the TrA (Rankin et al., 2006; Mannion et al., 2008; Linek et al., 2015d, 2016b). Thus, it seems necessary to take into account body mass as a confounder in all studies involving TrA

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thickness (Linek et al., 2016b). Controlling of body mass in these studies can be achieved by at least two methods, firstly by introducing body mass as a covariate in a statistical model and, secondly, by using a scaling procedure (ratio or allometric). The main problem with the first method is that multiple underlying assumptions have to be met to properly perform such an analysis. Because of this, the scaling procedure (ratio or allometric) seems to be a more practical and easier way to normalise US thickness of the TrA to body mass. The ratio scaling procedure assumes a linear relationship between a physiological measurement and body mass; whereas the allometric scaling procedure is based on the theory of geometrical symmetry suggesting that all humans have the same shape but are of different sizes (Jaric et al., 2005). Nuzzo and Mayer (2013) recommended that allometric scaling is better than ratio scaling for TrA muscle normalisation. In practice, the allometric method requires a constant value of the allometric parameter (the so-called exponential power), which is then used to normalise the TrA measurement to body mass with the use of a simple equation (Jaric et al., 2005). To date, the allometric parameter for TrA has only been assessed in a healthy adolescent population; the value was 0.61 (Linek et al., 2016b).

Some studies evaluating TrA muscle thickness did not consider body mass as a confounder (Springer et al., 2006; Mannion et al., 2008; Rho et al., 2013; Gildea et al., 2014; Linek, 2015; Linek et al., 2015d; Rostami et al., 2015a), which may have led to inaccurate interpretations of the results. For example, gender differences may lead to misinterpretation as females often demonstrate lower resting thickness of the TrA compared to males (Rankin et al., 2006; Springer et al., 2006; Rho et al., 2013; Gildea et al., 2014; Linek et al., 2015d). In general, however, females also have a significantly lower body mass value (Rankin et al., 2006; Springer et al., 2006; Rho et al., 2013). Such cross-gender differences in TrA thickness may be caused by body mass (Rankin et al., 2006; Mannion et al., 2008; Linek et al., 2015d). The same problem of possible misinterpretation can also be seen in studies evaluating the effect of physical (sport) activity on TrA thickness. In a study in which a higher body mass value was identified in the sport group, the thickness of the TrA was also higher in that group (Linek, 2015); however, in a study in which body mass was similar between examined groups (active vs non-active), the thickness of the TrA was also similar (Linek et al., 2015a). Sitilertpisan et al. (2011) showed that athletes have significantly thicker TrAs than non-athletes in spite of possessing the same body mass value. The explanation for this is the muscle hypertrophy found in athletes resulting from regular sport training and competition. In turn, Belavý et al. (2016) found that prolonged bed rest leads to atrophy of the TrA. Thus, it is possible that professional sports training (regular physical activity) or a more sedentary life style could influence TrA morphology. However, the findings noted above indicate that inter- and intra-group comparisons of the TrA should not be performed without controlling for body mass, because hypothetical group differences may be simply explained by differences in body mass, as pointed out by (Gildea et al., 2014; Linek, 2015).

The same problem can be seen in the analysis of age effects on TrA thickness. Rankin et al. (2006) identified a small and negative correlation exists between age and abdominal muscle thickness; whereas Mannion et al.'s (2008) found no correlation between TrA and age. Ikezoe et al. (2012) found no differences in TrA thickness between young and independent elderly women. In the adolescent population, in which there are usually rapid increases in body mass over a short period of time, a correlation between TrA thickness and age may be expected. However, such an analysis without TrA normalisation to body mass may lead to further misinterpretation.

Therefore, the confounding effect of body mass on TrA thickness is important in both adolescent and adult populations but, because in adolescence weight is physiologically doubled in the short period of time from the age of 10–17 (DiMeglio et al., 2011), TrA normalisation is of greater importance in adolescent populations. Additionally, such rapid changes in body mass value in adolescent population may also complicate the evaluation of the effectiveness on TrA morphology of some specific exercises. Our own unpublished data from a randomised-controlled trial investigating the effects of balance exercises on lateral abdominal muscles showed that, during the few months of observation, the body mass significantly increased in adolescent aged 10–17 years. Thus, a possible positive effect of such a controlled trial on TrA may also be explained by changes in body mass. All these factors indicate the necessity for body mass normalisation in scientific research. The present study is the first to address the problem of misinterpretation of the results of TrA thickness analysis in an adolescent population due to differences in body mass. Potential confounders such as age, gender and sport practice were used as an example to highlight the problem. The aims of the study were: 1) to assess differences in the effects of age, gender and physical activity between values normalised for body mass and actual of the TrA, and 2) to establish the effect of age, gender and physical activity on normalised for body mass TrA thickness (the effect independent of body mass).

2. Material and methods

2.1. Setting and study design

This was a cross-sectional study conducted at selected primary and secondary schools and colleges in the Silesian region of Poland. The study was designed in accordance with the Declaration of Helsinki and was approved by the local medical ethics committee. All participants and their parents and/or legal guardians received oral and written information about all procedures and gave their signed informed consent to participate.

2.2. Study population

The study population, between the ages of 10 and 17, was selected from local schools and colleges and attended regular school classes at normal grade levels. At the beginning of the study, participants answered questions related to their medical history. Information from the child's health record at school was also analysed. At this stage, the following individuals were excluded: 1) those in whom any surgical procedure had been performed on the pectoral chest, the abdominal cavity, the pelvic girdle and/or the spine; 2) those with a chronic cardiovascular/respiratory system disorder; 3) those who had experienced pain in the spine, pelvic girdle and/or lower limbs during the three months preceding the study.

For all included participants the Adams test was performed and body rotation (axial trunk rotation – ATR) was tested with a scoliometer; this is a common measurement used in screening for scoliosis in adolescents (Fong et al., 2010). During measurement, all participants were barefoot. Boys were evaluated shirtless, and girls wore a swimsuit that allowed the entire back to be seen. Female participants also had their hair tied up. Finally, each subject responded to questions about current and past physical activities. This was the basis for dividing participants into two groups: individuals who did do not practise, any had not practised, any sports were included in the non-physically active group (Sport – no). Individuals who stated that they had belonged to a sport club for at least one year, and therefore regularly practised a specific sport, were included in the physically active group (Sport – yes). Detailed data are presented in Table 1.