Age-related changes in concentric and eccentric isokinetic peak torque of the trunk muscles in healthy older versus younger men

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Abstract

This study investigated age-related changes in trunk muscle function in healthy men and the moderating effect of physical activity (PA).

Twelve older (67.3±6.0 years) and 12 younger (24.7±3.1 years) men performed isokinetic trunk flexion and extension tests across a range of angular velocities ($15°\cdot s^{-1}$ - $180°\cdot s^{-1}$) and contractile modes (concentric and eccentric).

For concentric trunk extension, mixed-effects ANCOVA revealed a significant interaction between angular velocity x age group ($p=.026$) controlling for PA. Follow-up univariate ANCOVA revealed that the younger group produced significantly greater peak torque for all concentric extension conditions. Eccentric trunk strength was somewhat preserved in the older group. Age-related changes in trunk strength were independent of PA.

The normal loss of trunk muscle strength in older age is muscle and contractile mode specific. These findings provide guidance for effective intervention strategies to offset adverse health outcomes related to trunk strength loss in older adults.

Key words: muscle strength, ageing, sarcopenia, abdominal muscles, paravertebral muscles

Introduction

Skeletal muscle atrophy is associated with muscle weakness, however, studies have shown that the rate of strength loss is disproportionately greater than muscle atrophy (Delmonico et al., 2009; Mitchell et al., 2012) and better in predicting adverse outcomes (Menant et al., 2017; Schaap, Koster, & Visser, 2013). Indeed, low muscle strength is now the principal determinant for identifying sarcopenia (Cruz-Jentoft et al., 2019). Studies investigating age-related declines in muscle function typically focus on the appendicular musculature (Mitchell et al., 2012), despite growing evidence for the importance of trunk muscles in performing activities of daily living (ADLs) (Granacher, Gollhofer, Hortobágyi, Kressig, & Muehlbauer, 2013; Hicks et al., 2005) and constituting an important factor for overall health (Cho et al., 2014; Crawford, Volken, Valentin, Melloh, & Elliott, 2016; Valentin, Licka, & Elliott, 2015).

The abdominal and lumbar paravertebral muscles are inextricably linked, controlling trunk movement and promoting mechanical stability in the lumbopelvic region (Barr, Griggs, & Cadby, 2005; Cholewicki, Juluru, & McGill, 1999; Gardner-Morse & Stokes, 1998). The importance of maintaining strength in the lumbar extensor muscles is highlighted by the large forces they generate. Due to a relatively small moment arm, the lumbar extensor muscles must produce a substantially larger force than the weight of the upper torso and ventral loads to counterbalance the external moment. In older adults, decreased neuromuscular control of the trunk muscles compromises their ability to stabilise the spine in response to perturbations in the environment, which increases susceptibility to injury (Hwang, Lee, Park, & Kwon, 2008; Mannion, Adams, & Dolan, 2000). A strength reserve is therefore needed to react to unpredictable occurrences such as falls, sudden loading of the spine and quick movements (Barr et al., 2005). A sudden need to regain spinal stability may also result in excessive muscle activity; a mechanism implicated in the onset of lower back pain and injury (Cholewicki & McGill, 1996; Mannion et al., 2000). Since older adults exhibit slower trunk movements (McGill, Yingling, & Peach, 1999), it is imperative that trunk strength is maintained for balance (Granacher et al., 2013) and to mitigate excessive muscle activity in response to instability (Anderson & Behm, 2005). Therefore, maximum strength of the trunk muscles is an important factor in older adults when dynamic stabilisation is required (Rantanen, Era, & Heikkinen, 1994).

Studies using dynamometric approaches to evaluate trunk strength have typically opted for isometric conditions (Granacher, Lacroix, Roettger, Gollhofer, & Muehlbauer, 2014; Hernandez, Goldberg, & Alexander, 2010; Kassebaum et al., 2016; Porto et al., 2020; Sasaki et al., 2018; Shahtahmassebi, Hebert, Hecimovich, & Fairchild, 2017; Sinaki, Nwaogwugwu, Phillips, & P. Mokri, 2001). Although isometric measures provide valid and reliable outcomes for peak torque of the trunk musculature (De Blaiser, De Ridder, Willems, Danneels, & Roosen, 2018; Roth, Donath, Kurz, Zahner, & Faude, 2017), torque measured at a single standardised joint angle may not reflect muscle function across the functional range of motion (ROM) effectively (Rousanoglou & Boudolos, 2008). Given that torque production is joint angle dependent (Samuel & Rowe, 2009), measurement at one or a few discrete joint angles provides limited information about the force generating capacity of the muscles. Continuous measurement of joint torque elicits more detailed evaluation of a muscle group's function under controlled movement conditions. Furthermore, assessing force generation whilst the muscle is shortening and lengthening is more indicative of dynamic muscle activity during ADLs. Indeed, isokinetic dynamometry is widely regarded as the gold standard for dynamic muscle performance testing (Dvir, 2004; Felicio et al., 2014).

The effect of ageing on isokinetic trunk strength has been seldom studied with only a few studies reporting on adults over 50 years of age (Danneskiold-Samsøe et al., 2009; Gomez, Beach, Cooke, Hrudey, & Goyert, 1991; Hasue, Fujiwara, & Kikuchi, 1980; Hulens, Vansant, Lysens, Claessens, & Muls, 2002; Langrana & Lee, 1984; H. J. Lee et al., 2012). Of these studies, the effect of age on trunk strength varies from insignificant to large and it is unclear whether the age-response is equivalent between the abdominal and paravertebral muscles. Confounding factors which are often overlooked, such as PA level, may also moderate the age-response (Rantanen, Era, & Heikkinen, 1997). Furthermore, the lack of consensus regarding isokinetic parameters, such as ROM limits, angular velocity and contractile mode, precludes conclusions from being drawn on age-related loss of trunk strength. Most importantly, research on eccentric trunk strength with respect to ageing does not exist to the authors' knowledge, leaving a considerable gap in our understanding of muscle function in older age.

The loss of strength in older age is detrimental to physical function and is associated with adverse health outcomes, however, normal age-related decline in trunk strength is not fully understood. Assessing trunk strength at a range of angular velocities and under dynamic contractile modes is important to further our understanding of ageing trunk muscle function under conditions that reflect trunk kinematics during ADLs. This understanding will inform efforts to extend the period older adults are able to live independently. Therefore, this study aimed to investigate age-related changes in peak isokinetic trunk muscle torque across a range of contractile modes in healthy young and older men. A secondary aim was to evaluate the moderating effect of PA.

Methods

Reporting of this prospective observational study is based on the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement (von Elm et al., 2007). Coventry University Ethics Committee approved the study (P70399) on 13th September 2018. Participants were recruited between November 2018 and June 2019 from the community and from University staff and students in Coventry, England. Inclusion criteria were healthy males aged 18 – 30 years or above 60 years. Individuals who had a BMI outside of 18.5 – 29.9 $kg \cdot m^{-2}$, smoked, consumed alcohol on a daily basis or had an existing or past medical history of metabolic diseases, neuromuscular disorders or musculoskeletal impairments that may affect muscular strength were excluded. Younger participants were matched to older participants based on PA level (IPAQ-SF) (Craig et al., 2003) and ethnicity. Informed written consent was obtained from all participants, and suitability to undergo the protocol was assessed through a pre-test health questionnaire and the Modified Oswestry Low Back Pain Disability Questionnaire (ODQ-m) (Fritz & Irrgang, 2001) immediately prior to testing. A priori sample size estimation was performed in G* Power (Version 3.1.9.2) using means and standard deviations from a previous study (Danneskiold-Samsøe et al., 2009) assessing isokinetic trunk torque in a similar population of healthy younger and older men. Based on large observed effect sizes, a sample size of eight participants per group was calculated (α-error = 0.05, β-error = 0.8). This study enrolled 12 healthy older men (67.3 ± 6.0 years) and 12 healthy younger men (24.7 ± 3.1 years). Height and mass were measured in addition to whole-body and segmental lean mass and whole-body fat mass using bioelectrical impedance analysis (Tanita MC-780MA S, Tanita, Tokyo, Japan).

Isokinetic dynamometry

A Trunk Modular Component (TMC) docked to a HUMAC® NORM™ isokinetic dynamometer (HUMAC® NORM™ Testing and Rehabilitation System, CSMI, MA, US) with proprietary software (HUMAC® 2009, v10.000.0082) was used for data acquisition. Calibration was performed according to the manufacturer's guidelines before each testing session. Prior to testing, the TMC was adjusted for each participant to ensure alignment of the dynamometer axis to the rotation axis of the trunk while in a comfortable standing position (Figure 1). Participants held the downward-facing handle in front of the chest to prevent motion of the upper limbs. Restricting upper-body motion and stabilising the lower body was performed to avoid extraneous movements and minimise the unwanted contribution of muscles not being tested. Whilst standing with a neutral spine, the participant's anatomical zero position was determined as an angle of 0°

between the trunk and thighs. Mechanical stoppers were applied as a safety precaution. Gravity correction was performed according to the manufacturer's instructions to minimise differences in upper-body mass between participants and the effect of gravity on reciprocal muscle groups.

Familiarisation

Participants performed a familiarisation session at least 10 days before testing to ensure adequate recovery. Participants were instructed to perform the familiarisation session at sub-maximal effort, approximately 50 % maximal voluntary contraction (MVC), to prevent excessive muscle damage (Deschenes et al., 2000). In accordance with previous studies (Ly & Handelsman, 2002), familiarisation was considered complete when participants were confident in performing the trials consistently for each condition. Confirmation was sought by visually inspecting torque-time graphs, where participants were able to successfully perform three sub-maximal consecutive contractions. Participant positioning and initial dynamometer set-up was performed and recorded during the familiarisation sessions and recalled during experimental trials.

Protocol

Participants abstained from caffeine ingestion on the day of testing and from undertaking strenuous PA within seven days of testing. A five-minute warm-up on a cycle ergometer (Wattbike Ltd, Nottingham, UK) against low resistance (target power = 50 W; cadence = 60-80 rpm) was completed before participants performed a series of sub-maximal concentric flexion/extension contractions on the TMC through a full range of motion to specifically target the trunk musculature. During these sub-maximal contractions, the testing ROM was determined by reducing the participant's maximum ROM by 10° from maximum extension and flexion to minimise the injury risk and allow sufficient force production to initiate movement during the eccentric trials. Prior to each test condition, participants performed five sub-maximal efforts (≈ 50 % MVC) that replicated the test. This approach ensured sufficient preparation and correct performance whilst serving as another familiarisation to minimise learning effects. Following the warm-up trials, participants rested for as long as required until they felt fully recovered and prepared for the three reciprocal flexion and extension MVCs. During the measurement verbal encouragement was given to facilitate maximal voluntary efforts (Matheson et al., 1992). The protocol is shown in Table 1. Contractions at slower angular velocities were tested first to increase the reproducibility of results between conditions (Karataş, Göğüş, & Meray, 2002; Wilhite, Cohen, & Wilhite, 1992). To avoid inflated concentric torques augmented by preceding eccentric contractions (Finni, Ikegawa, Lepola, & Komi, 2003; W. Herzog, Schappacher, DuVall, Leonard, & Herzog, 2016), reciprocal muscle groups were paired (i.e. extensor contraction followed by flexor contraction) with inter-contraction pauses of at least five seconds. Due to the strenuous nature of the slower angular velocity contractions, longer pause times were given if required to ensure the participants' safety and recovery. To prevent the cumulative effects of fatigue influencing MVC torque (Gregory, Narula, Howarth, Russell, & Callaghan, 2008), a minimum of 60 seconds rest time was given between test conditions. If the participant required more rest time, this period was extended until the sensation of fatigue abated. A maximum rest time was not prescribed due to the individualised recovery response to fatigue, especially between older and younger adults.

Data processing

Torque, angular velocity and trunk angle data were acquired at a sampling rate of 100 Hz. The analogue torque signal from the dynamometer was filtered and digitised by the system's Digital Signal Processor (CYBEX, 1995). Data were exported and analysed in Microsoft Excel (Microsoft® Excel ® for Office 365 Version 16.0, Redmond, WA, US). For each test condition, the contraction which displayed the greatest peak torque was used for analysis. Peak torque values were identified during the isokinetic phase of the movement. Data which were not within 5% of the target velocity were discarded. In addition, the first 20 consecutive data points that fell within the target velocity limits signified the start of the isokinetic phase. These constraints were designed to remove artefacts associated with torque overshoot and impacts at the start and end of the movement. Torque values were normalised to body mass to reduce the effect of inter-subject variation in body size.

Physical activity measurement

Participants wore an Actigraph GT9X accelerometer, sampling at 90 Hz, on their dominant wrist for seven consecutive days. The decision for wrist-worn accelerometers was made due to wear-time compliance and hip placement potentially lacking the sensitivity to reflect less traditional modes of PA more commonly performed in older adults (Walsh, Pressman, Cauley, & Browner, 2001). The dominant wrist was preferred due to greater PA classification accuracy than the non-dominant wrist, albeit a negligible difference (Zhang, Rowlands, Murray, & Hurst, 2012). Data were processed using dedicated software (Actilife, version 6.13). To ensure data were representative of PA performed in a typical day and week, wear-time criteria were established. Data must have been obtained for a minimum of four days including one weekend day and at least 10 hours of awake time during these days. Valid data were divided into 1 second epochs to increase accurate identification of high intensity bursts of activity. Average time (hours) spent per day in moderate-to-vigorous PA (MVPA) and vigorous PA (VPA) were calculated using cut-off values of 1031 counts/minute for moderate and 3589 counts/minute for vigorous intensities (Diaz et al., 2018).

Statistical analysis

Statistical analyses were performed using SPSS (SPSS® for Windows Version 24.0, IBM Corp, Armonk, New York) and graphical presentation performed using GraphPad Prism (Version 8.3.1, San Diego, California). Data are presented as means with standard deviations (mean ± SD) unless otherwise stated. For demographic, anthropometric, PA and questionnaire data, independent samples t-tests were performed to compare statistical differences between the old and young groups. For the isokinetic data, two-way mixed-effects ANCOVA (angular velocity x age group) controlling for VPA were performed to compare mean differences in peak torque between the old and young groups. Concentric and eccentric conditions for the extensors and flexors were analysed separately. Following a significant interaction or main effect, multiple univariate ANCOVA with Bonferroni adjustments were performed to assess significant differences between age groups for each test condition. An alpha level of 0.05 was required for statistical significance. Effect size (η_p^2) and observed power (1-β) were also determined for each comparison. Data for all conditions were normally distributed (Shapiro-Wilk test, $p > .05$) and homogeneous variances were assumed (Levene's test, $p > .05$). The assumption of sphericity was violated (Mauchly's test < .05), therefore, Greenhouse-Geisser corrections were adopted.

Reliability

A sub-sample (n = 10) of five old and five young participants repeated the test protocol after 16 weeks to assess long-term intra-operator reliability. The same researcher (AD) conducted the retests and analysed the data. For each test condition, intra-class correlation coefficients (ICC) for peak torque were calculated using single-measurement, absolute-agreement, two-way mixed-effects models. Linear regression (difference vs mean) was also used to determine the existence of proportional bias for each test condition ($p \leq .05$).

Results

Participant characteristics are presented in Table 2. There were no statistical differences in height, mass, BMI, MVPA, whole-body lean mass and ODQ-m scores between the groups. The older group had more fat mass ($t_{(22)} = 2.62$, $p = .016$), less appendicular muscle mass ($t_{(22)} = 3.28$, $p = .003$) and engaged in less VPA

($t_{(22)} = -2.37$, $p = .027$) than the younger group. Whilst the older group exhibited a smaller trunk ROM ($t_{(22)} = 2.85$, $p = .009$) than the younger group, maximum extension and flexion trunk positions were not statistically different between groups ($p > .05$).

Isokinetic dynamometry

Mixed two-way ANCOVA revealed a significant interaction between angular velocity x age group ($F_{(3.3,69.8)} = 3.2$, $p = .026$) for concentric contractions of the trunk extensor muscles after controlling for VPA ($F_{(1,21)} = 0.32$, $p = .581$). Significant main effects for age group ($F_{(1,21)} = 19.9$, $p < .001$) and angular velocity ($F_{(3.3,69.8)} = 3.6$, $p = .015$) were also revealed, showing that the younger group produced greater peak concentric extension torque (4.64 $N\cdot m\cdot kg^{-1}$) than the older group (3.04 $N\cdot m\cdot kg^{-1}$) and that both groups showed a general decline in peak concentric extension torque with increasing angular velocity. No significant interactions or main effects were observed for any other condition. Appendicular lean mass was not a significant covariate of trunk extensor concentric strength between groups ($F_{(1,21)} = 0.03$, $p = .866$). Peak torque data are presented in Table 3.

One-way univariate ANCOVA (Bonferroni adjustment) revealed significant differences between the old and young groups at all angular velocities for concentric trunk extension. At

- $15°\cdot s^{-1}$ ($F_{(1,21)} = 14.0$, $p = .001$, $\eta_p^2 = 0.399$, $1-\beta = 0.945$);
- $30°\cdot s^{-1}$ ($F_{(1,21)} = 13.0$, $p = .002$, $\eta_p^2 = 0.382$, $1-\beta = 0.930$);
- $45°\cdot s^{-1}$ ($F_{(1,21)} = 12.0$, $p = .002$, $\eta_p^2 = 0.364$, $1-\beta = 0.911$);
- $60°\cdot s^{-1}$ ($F_{(1,21)} = 14.0$, $p = .001$, $\eta_p^2 = 0.399$, $1-\beta = 0.945$);
- $90°\cdot s^{-1}$ ($F_{(1,21)} = 20.2$, $p < .001$, $\eta_p^2 = 0.491$, $1-\beta = 0.990$);
- $120°\cdot s^{-1}$ ($F_{(1,21)} = 20.9$, $p < .001$, $\eta_p^2 = 0.499$, $1-\beta = 0.992$) and;
- $180°\cdot s^{-1}$ ($F_{(1,21)} = 19.0$, $p < .001$, $\eta_p^2 = 0.475$, $1-\beta = 0.986$)

the younger group produced significantly greater peak concentric extensor torque than the older group. Peak concentric extensor torque was generally consistent from $15°\cdot s^{-1}$ to $60°\cdot s^{-1}$ for both groups. The older group exhibited decrements thereafter, whilst the younger group showed declines from $120°\cdot s^{-1}$. This resulted in a trend for increasing difference between old and young groups as angular velocity increased past $45°\cdot s^{-1}$ (Figure 2). Significant pairwise differences ($p < 0.001$) in concentric extension peak torque were found between $120°\cdot s^{-1}$ and $180°\cdot s^{-1}$ and between each other these conditions with all other angular velocities.

Reliability

Test-retest reliability was good to excellent across the range of test conditions for the concentric extensor trials (Table 4). Test-retest reliability was moderate to excellent for the concentric flexor trials (ICC = 0.60 – 0.92), good to excellent for the eccentric extensor trials (ICC = 0.78 – 0.92) and moderate to good for the eccentric flexor trials (ICC = 0.72 – 0.86). ICC values for these test conditions are presented in appendix b. For every test condition, regression coefficients were not significant ($p > .05$), indicating that proportional bias was not present.

Discussion

The current study demonstrates for the first time that the normal loss of dynamic trunk muscle strength in older age is muscle and contractile mode specific. The main finding was that trunk extensor muscles experience an age-related decrement in concentric strength and the age-effect increases with increasing angular velocity. Eccentric strength is also somewhat preserved in the trunk flexors and extensors across angular velocities from $15°\cdot s^{-1}$ to $60°\cdot s^{-1}$. A progressive decline in muscle strength typically accompanies the ageing process, however, normal age-related decrements in the lumbar musculature are not fully understood. Given the inconsistent methods and equivocal nature of findings on this topic, this work provides an in-depth investigation into age-related changes in trunk strength and constitutes an important contribution to the literature base to date.

Loss of extensor concentric torque

The results show that healthy males experience a loss of concentric extensor torque with ageing in the trunk. As the proportion of contractile tissue in the lumbar paravertebral muscles decreases due to age-related atrophy and fat infiltration (Dallaway et al., 2020), the muscles' capacity to generate force and perform work is reduced (Ropponen, Videman, & Battié, 2008). However, lean trunk mass was greater in the older group than the younger group in this study. Whilst the extensor and flexor muscle masses cannot be separated in the current analysis, it is unlikely that atrophy of the paravertebral muscles caused decreases in concentric extension torque. Neurological changes in older age are more likely to have contributed to declines in trunk strength.

Neuropathic processes in older age bring about a decline in neural drive and cause muscle to express a slower phenotype (Campbell, McComas, & Petito, 1973; Evans & Lexell, 1995). The increasing disparity between groups in concentric extension torque with increasing angular velocity (Figure 2) suggests a shift towards a slower fibre-type composition in the older group. Indeed, muscles in the lumbar spine have a propensity towards slower isoforms (Regev et al., 2010). Given that the intrinsic strength of type I fibres is less than type II fibres (Bottinelli, Canepari, Pellegrino, & Reggiani, 1996; Young, 1984), an increasing proportion of slow-twitch fibres is likely to reduce muscular force production resulting in a loss of concentric extension strength (Ivy, Withers, Brose, Maxwell, & Costill, 1981; Robles et al., 2015). This age-related remodelling of muscle phenotype may explain why loss of concentric extensor torque is greater with increasing angular velocity and more pronounced in the older group.

Attenuation of flexor concentric torque

The older group exhibited lower concentric flexion torque, although differences with the younger group did not reach significance for any of the angular velocities. Similar findings have been previously reported (Smith, Mayer, Gatchel, & Becker, 1985), although not undisputed (Hasue et al., 1980; Skrzek & Bolanowski, 2006). Hasue et al. (1980) suggested that the discrepancy in abdominal and paravertebral muscle strength may be due to the constant use of antigravity muscles in daily life whereas intra-abdominal pressure aids the function of the abdominal muscles. It is also likely that the apparent attenuation in trunk flexion strength is the result of abdominal morphometry preservation. Whilst the relative degeneration of the abdominal muscles compared to the paravertebral muscles cannot be determined in the current study, it has been shown that the abdominals are relatively spared from the effects of age-related degeneration compared to the paravertebral muscles (Meakin, Fulford, Seymour, Welsman, & Knapp, 2013; Valentin et al., 2015). This may preserve the contractile unit of the abdominal muscles relative to the paravertebral muscles, which may explain why concentric flexion torque was not significantly different between the old and young groups whilst concentric extension torque was.

Preservation of eccentric strength in older age

This study found that both extensor and flexor muscle groups in the trunk experience a relative preservation of eccentric strength with ageing. To the authors' knowledge, this is the first study to investigate the effect of healthy ageing on eccentric trunk strength, which precludes comparisons with other studies. Age-related preservation of eccentric strength has been observed in other muscle groups (Klass, Baudry, & Duchateau, 2005; Poulin, Vandervoort, Paterson, Kramer, & Cunningham, 1992) although no mechanisms have been fully accepted (Hortobágyi et al., 1995; Roig et al., 2010). Compared to concentric contractions, muscle exhibits significantly lower neural activation at a given force output during eccentric contractions (Kellis & Baltzopoulos, 1998). Concentric contractions are also affected by increased antagonist coactivation in old age (Larsen, Puggaard, Hämäläinen, & Aagaard, 2008; Macaluso et al., 2002) whilst the effect is diminished in eccentric contractions (Kellis & Baltzopoulos, 1999). Therefore, age-related deficits in neural drive (Häkkinen et al., 1996; Rods, Rice, & Vandervoort, 1997; Unhjem, Lundestad, Fimland, Mosti, & Wang, 2015) are likely to have greater impact on concentric contractions than eccentric. Alterations in the passive structural elements and intrinsic factors associated with cross-bridge cycling may also mediate the relative preservation of eccentric strength (Walter Herzog, 2014; Hill, Wdowski, Pennell, Stodden, & Duncan, 2019; Power, Rice, & Vandervoort, 2012). In the current study, lean mass in the trunk was unable to explain the preservation of eccentric strength. This supports Hortobágyi and colleagues (1995) who state that eccentric strength is maintained independent of age-related morphometric muscle changes.

Mechanisms regarding preservation of eccentric strength in older age focus on neurological, cellular and mechanical pathways (Hortobágyi et al., 1995; Roig et al., 2010), however, none consider biomechanical function, especially relating to the trunk. Thoracolumbar bending moment increases with ageing due to postural changes (Le Huec et al., 2018). The extensor muscles are subsequently activated to prevent forward flexion of the trunk (Cresswell, Oddsson, & Thorstensson, 1994; Waters & Morris, 1972), which increases mechanical energy expenditure required for eccentric control of the lower trunk musculature (McGibbon & Krebs, 2001). Despite the low-level activity of trunk muscles during ADLs (McGill & Cholewicki, 2001), sustained low-intensity eccentric activation may provide enough stimulus for the muscles to maintain their strength. Whilst speculative, these suggestions are plausible and attempt to understand this phenomenon in a holistic manner. More importantly, the current results in the trunk reflect the eccentric strength age-response observed in the appendicular muscles (Klass et al., 2005; Poulin et al., 1992). This suggests that eccentric strength preservation is systemic rather than a muscle- or site-specific phenomenon in the body.

Moderating effect of physical activity

PA is generally believed to have a positive effect on muscular strength in older adults (Rantanen, Era, Kauppinen, & Heikkinen, 2016). Whilst VPA is more beneficial, low-intensity PA can still lead to better functional ability (Avlund, Schroll, Davidsen, Løvborg, & Rantanen, 1994). However, the results of this study suggest that habitual VPA does not moderate age-related changes in trunk strength amongst healthy men. Previous research in a large community-dwelling population supports this finding (Viljanen, Viitasalo, & Kujala, 1991). It was suggested that the small proportion of adults engaging regularly in resistance training (< 1 %) may have been insufficient to observe a training effect on maximal isometric trunk strength in their sample (Viljanen et al., 1991). In the current study, PA was measured using accelerometery and a recognised limitation of using accelerometers is their inability to detect non-ambulatory activities such as resistance exercise (I. M. Lee & Shiroma, 2014; Viljanen et al., 1991).

Clinical and practical applications

In clinical settings, understanding the age-related loss of trunk strength could be crucial due to its association with physical function (Shahtahmassebi et al., 2017), lower back pain (Cho et al., 2014) and falls risk (Granacher et al., 2013). Whilst the rehabilitation of upper and lower limb muscles is often based on the relative strength of the unaffected limb, bilateral comparisons cannot be made in the trunk. Therefore, age-specific normative trunk strength values across a range of contraction types and angular velocities are needed to allow healthcare professionals to evaluate a patient's trunk strength and determine an effective rehabilitation intervention. Based on the current results, slower angular velocities than $60°\cdot s^{-1}$ may not provide additional information about the maximal force generating capacity of trunk muscles in healthy men. The substantial decline in concentric trunk extension torque from $90°\cdot s^{-1}$ to $180°\cdot s^{-1}$ indicates that investigation at greater angular velocities may be valuable. However, the range of conditions used in this study accounted for trunk activity typically observed during ADLs (Goutier, Jansen, Horlings, Kung, & Allum, 2010; Lindemann et al., 2014; Pigeon, Bortolami, Dizio, & Lackner, 2003). Faster conditions would represent more dynamic movements that may offer additional insight into injury mechanisms of the lumbar spine. Furthermore, these results should support the use of isokinetic testing in the trunk and establishment of normative data that could provide useful clinical guidelines for trunk assessment and rehabilitation.

Limitations

The first limitation of this study was that samples comprised of healthy physically active men. Caution should be taken when generalising these findings as the participants are unlikely to be representative of a general population. Generalising the findings to female populations should also be done with caution, as women tend to show greater declines in trunk muscle strength with age (Danneskiold-Samsøe et al., 2009; H. J. Lee et al., 2012). Comparison with diseased populations may however provide useful information regarding pathological deviations in trunk strength. The results suggested that the eccentric tests and concentric flexion test were underpowered. However, the sample size was large enough to observe sufficient power for the concentric extension test. These results should be used to determine sample sizes in future studies. Finally, whilst the current study highlights an important feature of age-related musculoskeletal decline, longitudinal studies are needed to infer causation.

Conclusion

This study demonstrates that ageing elicits a muscle and contractile mode specific response in isokinetic torque of the trunk muscles. Concentric extensor muscle strength declines with ageing whilst eccentric trunk strength appears to be relatively preserved. Peak torque of the extensor muscles decreased with increasing angular velocity for concentric contractions and was more pronounced in the older group. The increasing disparity in trunk extension strength at greater angular velocities was likely due to age-related neuropathic processes affecting the contractile function of the paravertebral muscles. PA level did not moderate age-related changes in trunk strength, although this may be due to the way in which PA was measured. These findings are a useful step in establishing effective clinical and public health intervention strategies that could be used to offset adverse health outcomes related to trunk strength loss in older adults. Future research should look to assess trunk strength in a range of populations using a longitudinal design, which may enable identification of pathological deviations.

Word count – 4665

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