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Is knee extension strength a better predictor of functional performance than handgrip strength among older adults in three different settings?

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ABSTRACT

Background: The first purpose was to examine whether knee extension strength is a better predictor of functional performance than handgrip strength among older adults (≥60 years). The second purpose was to identify functionally relevant cut-off values for muscle strength.
Methods: 770 community-dwelling older adults, 104 older adults living in assisted living facilities and 73 nursing home residents were included. Static strength, expressed in kg/kg body weight (BW), was measured using two field tests: handgrip (GRIP/BW) and knee extension (KNEE/BW) test. Functional performance was assessed with 6-Minute Walk Distance (6MWD, $N = 947$) and modified Physical Performance Test (mPPT, $N = 152$).
Results: Both GRIP/BW and KNEE/BW were positively correlated with functional performance in all settings ($p < 0.05$). In the community and nursing homes, both strength variables equally contributed to functional performance. In assisted living facilities, KNEE/BW ($R^2_{6MWD} = 0.39$ and $R^2_{mPPT} = 0.35$) was clearly a better predictor of functional performance than GRIP/BW ($R^2_{6MWD} = 0.15$ and $R^2_{mPPT} = 0.12$). GRIP/BW had no added value to KNEE/BW in order to explain the variance in functional performance. Functionally relevant cut-off values for static strength, for men and women respectively, were set at 0.40 and 0.31 for KNEE/BW and at 0.43 and 0.31 for GRIP/BW.
Conclusions: Handgrip and knee extension strength are both important predictors of functional performance in older adults. In assisted living facilities only, knee extension strength was clearly more predictive than handgrip strength. Both cut-off values appear to be highly sensitive to screen for functionally relevant muscle weakness in older adults.

1. Introduction

Human aging is accompanied with declines in muscle mass and in muscle strength (Mitchell et al., 2012). The decline in muscle strength has been associated with reduced mobility and functional performance and increased risk of falling in older adults (≥60 years) (Lauretani et al., 2003; Macrae, Lacourse, & Moldavon, 1992; Marsh et al., 2011; Yang, Ding, Luo, Hao, & Dong, 2013). Functional deterioration will eventually lead to a loss of independence, increased healthcare costs and institutionalization. Therefore, individuals at high risk for functional limitations need to be identified. Considering the association between muscle strength and functional performance, screening for functionally relevant muscle weakness is crucial in developing effective strategies to prevent or at least delay functional decline in the aging population.

For the quantification of muscle strength in older adults, dynamometric measures of handgrip and knee extension strength predominate (Bohannon & Magasi, 2014). Static handgrip strength measurements have been widely used in clinical practice because of their affordability, portability, simplicity and time-efficiency. Handgrip strength appears to be a good predictor of adverse outcomes such as hospitalization and mortality (Legrand et al., 2014). Even though handgrip strength has been proposed to reflect the overall strength status of an older individual (Visser, Deeg, Lips, Harris, & Bouter, 2000), differences in activities requiring upper and lower body strength recommend caution when using a single

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action to describe overall muscle strength (Bohannon, 2008; Bohannon, Magasi, Bubela, Wang, & Gershon, 2012).

Aging is associated with a greater percent decline in lower than in upper limb muscle size and strength, which could have important implications for using grip strength as a physical marker of lower limb strength for those at risk for functional decline (Frontera et al., 2000; Newman et al., 2003; Samuel et al., 2012). The knee extensors in particular appear to be crucial in a variety of functional tasks, such as walking, chair rising and stair climbing (Hughes, Myers, & Schenkman, 1996; Ploutz-Snyder, Manini, Ploutz-Snyder, & Wolf, 2002). In addition, knee extension strength is important to prevent falls and to maintain bone health of the proximal femur (Macrae et al., 1992; Matsui, Takemura, Harada, Ando, & Shimokata, 2013).

The abovementioned arguments highlight the need for quantifying knee extension strength in addition to handgrip strength in older adults. To date, isokinetic dynamometry is considered the golden standard for measuring knee extension strength in scientific research (Drouin, Valovich-mcLeod, Shultz, Gansneder, & Perrin, 2004; Osternig, 1986). However, its practical applicability is limited because it is complex, time-consuming and costly. As a consequence, alternative isometric strength tests that strive for a quick and simple administration have been developed. One of these alternative tests is based on the knee extension strength test of the Physiological Profile Assessment (Lord, Menz, & Tiedemann, 2003). This static field test is a simple test on a portable chair using a digital dynamometer to measure maximal isometric knee extension strength.

An important question is whether this field test for static knee extension strength is a good measure to predict functional performance in older adults. If that is the case, the knee extension strength test can be used to screen for functionally relevant muscle weakness in older adults. When considering the older population ($\geq$60 years), one should keep in mind that this population is highly heterogeneous, especially in level of functionality and dependence. To meet the diversity of needs among older adults, there are several housing facilities. The three primary housing facilities are the community setting, assisted living facilities and nursing homes. Given that older adults in these settings differ from each other in terms of needs related to functionality, it might be interesting to include separate analyses depending on the setting.

The first purpose of the current study was to examine whether static knee extension strength, measured with the field test, is a better predictor of functional performance in older adults ($\geq$60 years) than handgrip strength. The three different living settings, as described above, will be taken into account. For developing effective strategies to counteract functional decline, it is also important to be able to identify persons with muscle weakness. For grip strength, normative data and cut-off values for muscle weakness are available in literature (Bohannon, Peolsson, Massey-Westropp, Desrosiers, & Bear-Lehman, 2006; Lauretani et al., 2003). However, the literature lacks data on functionally relevant cut-off values for knee extension strength. To be useful for large-scale screening purposes, these cut-off values should be based on simple field tests. Therefore, the second purpose of the current study was to identify functionally relevant cut-off values for static knee extension strength.

2. Methods

2.1. Participants and study design

Data for this study were derived from five studies among older adults, conducted between 2009 and 2013 in Flanders, Belgium. These five studies included one validation study and four interventions studies in older adults, of which only the pretest data were included in these analyses (Martien, Delecluse, Seghers, & Boen, 2014; Pelssers et al., 2013; Van Hoecke, Delecluse, Bogaerts, & Boen, 2013; Van Roie, Delecluse, Coudyzer, Boonen, & Bautmans, 2013). Participants gave written informed consent and all procedures were approved by the human Ethics Committee of KU Leuven.

These five studies, performed by investigators of the same research group, were selected because of their similarity with respect to the inclusion and exclusion criteria and in outcome measurements. Eligible participants had to be 60 years or older. For the maximal strength tests, exclusion criteria were unstable cardiovascular disease, acute infections and tumors. For the measurement of knee extension strength, additional exclusion criteria were severe back problems and knee or hip prosthesis.

In total, 947 participants were included in the present study. Of these participants, 770 were community-dwelling older adults (67% women), 104 were older adults living in assisted living facilities (76% women) and 73 were nursing home residents (71% women).

2.2. Outcome measurements

2.2.1. Functional performance

2.2.1.1. 6MWT. The 6MWT was performed over a walking course of 20 m (American Thoracic Society, 2002). Participants walked up and down the course at a fast but comfortable pace, and the distance covered in 6 min (6MWD, in meters) was recorded.

2.2.1.2. mPPT. Although the 6MWT has been shown to be a good indicator of functional performance in older adults (Bean et al., 2002), it only includes walking ability. The mPPT is a functional test battery that covers a broader range of functional items by also including upper extremity performance. The mPPT consists of nine functional items related to daily activities. Seven items were derived from the physical performance test described by Reuben and Siu (1990): (i) lifting a book from waist height to a shelf at shoulder level, (ii) putting on and taking off a coat, (iii) picking up a penny from the floor, (iv) turning 360°, (v) walking 15 m, (vi) ascending one flight of stairs, and (vii) climbing four flights of stairs. These seven items were combined with (viii) the chair rise test and (ix) the Romberg test for balance described by Guralnik and co-workers (1994). This modified version of the PPT has been used in previous research (Brown, Sinacore, Binder, & Kohrt, 2000; Van Roie et al., 2011). The score of each item ranged from 0 (the inability to complete the task) to 4 (the highest level of performance), with a total mPPT score of maximum 36 points.

The mPPT was conducted in a subsample of institutionalized older adults (102 of assisted living facilities and 50 of nursing homes), as the mPPT might not discriminate well between older adults who do not suffer from functional limitations (often perfect scores on sub-items).

2.2.2. Muscle strength

2.2.2.1. Handgrip strength. Handgrip strength was measured using a Jamar hand dynamometer, which was adjusted for hand size. The test–retest reliability of this test has been found to be high in older adults (ICC $\geq$ 0.85) (Wang & Chen, 2010). Handgrip strength (in kg) was measured twice with the dominant hand, in a standing position with the arm hanging by side and the elbow fully extended (Oja & Tuxworth, 1995). The best of both trials was used for further analyses. To standardize, the maximal static handgrip strength was expressed relative to BW (GRIP/BW).

2.2.2.2. Knee extension strength. Lower extremity strength was measured using a digital Kern HCB dynamometer. A field test for isometric knee extension strength, inspired by the Physiological