SHORT COMMUNICATION

ASSOCIATION BETWEEN MEASURES OF MUSCLE STRENGTH AND PERFORMANCE OF DAILY ACTIVITIES IN PATIENTS WITH KNEE OSTEOARTHRITIS

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Objectives: **Most studies of knee osteoarthritis use isokinetic peak strength as a measure of muscle strength. However, estimated one-repetition maximum (1-RM) may have a stronger relationship than isokinetic peak strength with daily activities. The aim of this study was to test the following hypotheses: first, the estimated 1-RM is more strongly associated than isokinetic peak strength with daily activities; and secondly, the estimated 1-RM is most strongly associated with the 6-minute walk test (6MWT), followed by the Get Up and Go test (GUG test) and the stair-climb test.**

Methods: **Data were used for 177 patients with knee osteoarthritis from a randomized controlled trial on improving muscle strength. The patients had a mean age of 67.6 ± 5.8 years. Isokinetic peak strength was measured using a dynamometer, 1-RM was estimated with the 10-RM test, and physical performance was measured with the 6-minute walk test (6MWT), get-up and go test (GUG) test and stair-climb test, at the start and end of 12 weeks of resistance training. Linear regression analyses provided standardized betas (β) that were comparable between the different associations between measures of muscle strength and daily activities.**

Results: **Compared with the estimated 1-RM, isokinetic peak strength was more strongly associated with all performance-based measures. The associations between the estimated 1-RM and performance-based tests were not ranked in the order hypothesized (6MWT, GUG test, stair-climb test).**

Conclusion: **Contrary to the first hypothesis, isokinetic peak strength showed stronger associations with all daily activities than did estimated 1-RM. In addition, the second hypothesis regarding the activity-specific pattern for the 1-RM with regards walking, chair rising and stair climbing measurements was not confirmed.**

Key words: osteoarthritis; knee joint; muscle strength.

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LAY ABSTRACT

In patients with knee osteoarthritis, greater muscle strength in the upper leg is linked with better performance in daily activities. To test muscle strength, peak muscle strength is usually measured. This study hypothesized that another test (the one-repetition maximum test) would be a more relevant measure. However, this was not confirmed, and therefore peak muscle strength remains the best measure of muscle strength at present.

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Increased thigh muscle strength is associated with better performance in daily activities in patients with knee osteoarthritis (OA) (1). Most studies of knee OA use isokinetic peak strength as a measure of muscle strength (2). Isokinetic peak strength is associated with performance-based measurements of daily activities in patients with knee OA, such as the 10-metre walk test ($\beta = -0.420$, $p < 0.001$), the Timed Up and Go test including getting up from a chair ($\beta = -0.452$, $p < 0.001$) and the stair-climb test ($\beta = -0.404$, $p < 0.001$) (3). Another measure of muscle strength is the one-repetition maximum (1-RM), which represents the maximum load at which a person can perform an exercise correctly for 1 repetition (4). Assessment of isokinetic peak strength includes only single-joint and concentric movements, which are uncommon when performing daily activities (5). In contrast, assessment of the 1-RM includes multi-joint movements and the coupling of eccentric and concentric actions, which are common in daily activities (5).

The first hypothesis of the current study was that the estimated 1-RM is more strongly associated with performance of daily activities than isokinetic peak strength in patients with knee OA.

Daily activities require a certain amount of muscle strength, which can vary greatly from activity to activity (6). Getting up from a chair and ascending or descending stairs requires 80%, 78% and 88% of the peak muscle strength of a healthy adult, respectively (6). Walking requires only 30% of the peak muscle strength of a healthy adult, but it has to be repeated for each step (6). Therefore, the ability to perform a movement repetitively (i.e. muscle endurance) may be more relevant to walking (4). Including multiple repetitions in a muscle strength measurement, as in the 10-RM test, may therefore be more strongly associated with walking, compared with tasks that are more demanding of peak strength, such as getting up from a chair and ascending or descending stairs (6). Therefore, the second hypothesis was that the estimated 1-RM is most strongly associated with walking, followed by getting up from a chair, and then with climbing stairs. Since muscle strength measurement is widely used in research in patients with knee OA (2), the current study may provide more insight into which measure is most appropriate for a specific research question addressing performance of daily activities. In addition, the study will provide insight into the strength of the associations between the estimated 1-RM and specific performance of tasks.

METHODS

This study used data from a randomized controlled trial (RCT) that focused on the effect of 12 weeks of high- or low-intensity resistance training (RT) and vitamin D or placebo supplementation on muscle strength in patients with knee OA. The current study analysed data from the measurements performed at the start and end of RT. All participants had been diagnosed with knee OA according to the clinical criteria of the American College of Rheumatology, were aged between 55 and 80 years old, and had a vitamin D (25(OH)D) level > 15 nmol/L.

A full description of the RCT study design is given in the original manuscript (ViDEX RCT, under review) (17). The study protocol was approved by the Medical Ethics Review Board (Reade/Sloterva-art hospital, NL47786.048.14) and was in compliance with the Declaration of Helsinki. Participants gave written informed consent.

Outcome measures

Measures of muscle strength. Isokinetic peak strength was assessed for peak extension of the knee, using an isokinetic dynamometer at 60°/s (EnKnee; Enraf-Nonius B.V., Rotterdam, The Netherlands) by a blinded assessor (7, 8). Excellent intra-rater reliability (intra-class correlation coefficient 0.93) has been reported for this measure in patients with knee OA (9). The estimated 1-RM was derived from the 10-RM test, which assesses the maximum load (kg) with which an exercise can be performed for 10 repetitions. A leg-press device (single-legged) was used to perform the 10-RM test. A trained physical therapist performed the test, during pre-determined resistance training sessions, after warming-up. Based on the results from 10-RM testing, the estimated 1-RM was calculated using the Brzycki formula (10). Excellent intra-rater reliability (ICC values ranging from 0.91 to 0.97) has been reported for this measure (5). Both isokinetic peak strength (Nm) and estimated 1-RM (kg) were divided by body weight and were part of the existing trial data.

Performance of daily activities. The 6-minute walk test (6MWT), the Get Up and Go test (GUG test), and the stair-climb test were used to assess performance of daily activities. For the 6MWT, patients walked their maximum distance in metres (m) in a 6-min period at a comfortable speed (11). For the GUG test, patients were timed (in s) while standing up from a chair (seat height 49 cm) and walking 15 m as fast as possible without running (12). For the stair-climb test patients were timed (in s) while ascending and descending (independently) a staircase with 12 steps, as fast as possible without running (13).

Patients' characteristics. Baseline demographics and clinical variables were obtained (i.e. age, sex, body mass index (BMI), Kellgren and Lawrence score (K&L) (14). Body mass and height were measured with participants in a standing position and clothed, but without footwear. BMI was calculated using the standard formula (kg/m^2). For knee-specific variables (muscle strength, K&L grade) data from 1 knee per person (Index Knee) were used. Index knees were determined by the knee pain in the previous week, and in case of an equal level of pain in both knees, 1 knee was chosen at random.

The use of paracetamol and non-steroidal anti-inflammatory drugs (NSAID) was assessed by questionnaire ("Did you use paracetamol or NSAIDs in the past month? (yes/no)"). Self-reported physical function was assessed using the Dutch translation of the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), subscale physical function (14, 15). The Longitudinal Aging Study Amsterdam Physical Activity Questionnaire (LAPAQ) was used to measure the level of moderate intensity physical activity (in min/day) (16).

Statistical analysis

Descriptive statistics for baseline participant characteristics were tabulated as means (standard deviation; SD), medians (interquartile range; IQR), or percentages for categorical variables. Delta scores were calculated for all outcome variables. Correlations (Pearson's *r*)

Table I. Patients' characteristics and outcome measures

	Start RT	End RT
Patients' characteristics		
Age, years	67.6 ± 5.8	–
Sex, % female	60.5	–
BMI, kg/m^2	28.2 ± 4.4	–
KL score, %		
0–1	39	–
2	32.2	–
3	15.8	–
4	13.0	–
Knee pain NRS	5.0 ± 2.4	–
Use of paracetamol in past month, % yes	44.8	–
Use of NSAID in past month, % yes	24.1	–
Total number of comorbidities (CIRS ≥2), %		
1	17.7	–
2	4.0	–
≥ 3	2.3	–
WOMAC-PF (0–68)	20 ± 13	–
LAPAQ total activity (min/day), median (IQR)	156 (99–221)	–
Vitamin D deficiency, % yes	28.2	–
Outcome measures		
Peak knee extension strength, Nm/kg	1.12 ± 0.49	1.24 ± 0.47
Estimated 1 RM on leg press, kg/kg	0.38 ± 0.20	0.65 ± 0.29
6MWT, m	505 ± 88	526 ± 88
GUG, s	10.4 ± 2.7	9.9 ± 2.2
Stair ascend, s	6.6 ± 3.3	6.1 ± 2.1
Stair descend, s	7.1 ± 4.0	6.4 ± 2.9

RT: resistance training; BMI: body mass index; KL score: Kellgren & Lawrence score, radiographic severity; NRS: numerical rating scale; CIRS: Cumulative Illness Rating Scale; WOMAC-PF: Western Ontario and McMaster Universities Osteoarthritis Index physical functioning; LAPAQ: Longitudinal Aging Study Amsterdam Physical Activity Questionnaire; 6MWT: 6-minute walk test; GUG test: Get-Up and Go test; NSAID: non-steroidal anti-inflammatory drugs.

were calculated between the 2 measures of muscle strength at the start and end of the resistance training and for the delta scores. Prior to the linear regression analysis, assumptions of linearity were checked. Muscle strength outcomes (isokinetic peak strength or estimated 1-RM) were the independent variables, and outcomes of the performance-based tests were the dependent variables. In addition, the association between isokinetic peak strength and estimated 1-RM was calculated. All analyses were corrected for age, sex, treatment allocation (high- or low-intensity RT) and vitamin D level. Both crude and adjusted values were presented. Linear regression analyses provided standardized betas (β) that were comparable between the different analyses. The closer a standardized beta was to –1 or 1, the stronger the association.

RESULTS

A total of 177 patients with knee OA were included in this study. Patients' characteristics at the start of RT are shown in Table I. Both isokinetic peak strength and estimated 1-RM improved over the 12 weeks of RT with 0.13 Nm/kg bodyweight and 0.27 kg/kg body weight, respectively (see Table I) (17). Isokinetic peak strength and the estimated 1-RM were correlated at the start ($r = 0.516$, $p = 0.00$) and end ($r = 0.533$, $p = 0.00$) of the RT, but no correlation was found for the delta score ($r = –0.026$, $p = 0.754$).

The standardized betas for the associations between the parameters of muscle strength and the performance-based tests are shown in Table II. Both isokinetic peak strength and estimated 1-RM were associated with the performance-based tests (6MWT, GUG test, stair descend and ascend) at the start and end of RT. Contrary to the first hypothesis, peak strength showed stronger associations (B closer to 1 or –1) with performance-based measures than the estimated 1-RM in all 8 analyses (see Table II).

To test the second hypothesis, the strength of associations for the estimated 1-RM were ranked from 1 to 4 at time-points , where 1 represents the strongest association and 4 the weakest association (see Table III). For the second hypothesis, the following rank order was expected: 1: 6MWT; 2: GUG test; and 3 and 4: stair-climb tests (ascend/descend, respectively). The data in Table III show that the hypothesized rank order was not present at the start or end of RT.

Table II. Associations between muscle strength and performance-based tests: testing the first hypothesis

	Start RT					End RT				
	Peak		1-RM		First hypothesis	Peak		1-RM		First hypothesis
	B crude	B adjusted	B crude	B adjusted	Peak vs 1-RM	B crude	B adjusted	B crude	B adjusted	Peak vs 1-RM
6MWT	0.483	0.443	0.359	0.261	Peak	0.596	0.552	0.389	0.344	Peak
	$p < 0.001$	$p < 0.001$	$p < 0.001$	$p = 0.001$		$p < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.001$	
GUG test	–0.477	–0.429	–0.353	–0.273	Peak	–0.581	–0.532	–0.399	–0.359	Peak
	$p < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.001$		$p < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.001$	
Stair-climb test										
Descend	–0.498	–0.482	–0.325	–0.260	Peak	–0.506	–0.499	–0.369	–0.376	Peak
	$p < 0.001$	$p < 0.001$	$p < 0.001$	$p = 0.002$		$p < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.001$	
Ascend	–0.472	–0.421	–0.281	–0.188	Peak	–0.602	–0.575	–0.393	–0.363	Peak
	$p < 0.001$	$p < 0.001$	$p < 0.001$	$p = 0.024$		$p < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.001$	

RT: resistance training; peak: peak knee extension strength; 1-RM: estimated 1-RM; 6MWT: 6-minute walking test; GUG test=Get-up and go test; B crude: standardized beta, unadjusted; B adjusted: standardized beta, adjusted for age, sex, treatment allocation (high- or low-intensity resistance training (RT)) and vitamin D level.

First hypothesis: the type of muscle strength with the strongest association is mentioned in this column (Peak or 1-RM)

Table III. Associations between muscle strength and performance-based tests: testing the second hypothesis

	Start RT					End RT				
	1-RM		Second hypothesis			1-RM		Second hypothesis		
	B crude	B adjusted	Hypothesized rank order	Actual rank order	Hypothesis rejected	B crude	B adjusted	Hypothesized rank order	Actual rank order	Hypothesis rejected
6MWT	0.359 $p<0.001$	0.261 $p=0.001$	1	2	Yes	0.389 $p<0.001$	0.344 $p<0.001$	1	4	Yes
GUG test	−0.353 $p<0.001$	−0.273 $p<0.001$	2	1	Yes	−0.399 $p<0.001$	−0.359 $p<0.001$	2	3	Yes
Stair-climb test										
Descend	−0.325 $p<0.001$	−0.260 $p=0.002$	3	3	No	−0.369 $p<0.001$	−0.376 $p<0.001$	3	1	Yes
Ascend	−0.281 $p<0.001$	−0.188 $p=0.024$	4	4	No	−0.393 $p<0.001$	−0.363 $p<0.001$	4	2	Yes

RT: resistance training; 1-RM: estimated 1-RM; 6MWT: 6-minute walking test; GUG test: Get-up and go test; *B* crude: standardized beta, unadjusted; B adjusted: standardized beta, adjusted for age, sex, treatment allocation (high- or low-intensity RT) and vitamin D level.

Second hypothesis: numbering 1–4 for strongest to weakest association with 1-RM.

[#]Ranking of strength of associations.

DISCUSSION

This study found the strongest associations between a measure of muscle strength and daily activities in patients with knee OA for isokinetic peak strength and not for the a priori hypothesized estimated 1-RM (first hypothesis). This finding was consistent for all 3 daily activities, both at the start and the end of RT. While the estimate of 1-RM, compared with the assessment of isokinetic peak strength, is more similar to the performance of daily activities (5), isokinetic peak strength showed stronger associations with daily activities than the estimated 1-RM.

The moderate association between isokinetic peak strength and the estimated 1-RM at the start and end of the RT suggest that these 2 measures of muscle strength may reflect different constructs. In contrast to our hypothesis, peak strength, as measured isokinetically on a dynamometer, is more closely related to the performance of daily activities in patients with knee OA, than the 1-RM, as derived from the 10-RM test. Based on these findings, isokinetic peak strength is the preferable measure for a specific research question addressing performance of daily activities.

For the estimated 1-RM, the association with 6MWT was not found to be stronger than the GUG test and the association with the GUG test was not found to be stronger than the stair-climb test. Therefore, the second hypothesis, that walking is most strongly associated with the estimated 1-RM, followed by the getting up from a chair and then the stair-climbing measurements, has to be rejected. A possible explanation for this finding is that the 10-RM test is not specific enough to measure muscle endurance mandated by walking. This is because the 10-RM test is a multiple repetition to failure test with only 10 repetitions, while a 6MWT contains hundreds of steps (4, 11). Therefore, future research is needed to test the second hypothesis including a more adequate measure of muscle endurance.

Strengths and limitations

Strengths of this study are the large sample size, the use of 2 measurement time-points and the presence of 2 outcomes of muscle strength. A possible weakness of the study is that, while the isokinetic peak strength was assessed by a blinded assessor in a laboratory setting, the trained physical therapist who assessed the estimated 1-RM during the treatment was not blinded for treatment allocation.

CONCLUSION

Contrary to the first hypothesis of this study, isokinetic peak strength showed stronger associations than the estimated 1-RM with all daily activities performed. Also, the second hypothesis, regarding an activity-specific pattern for the 1-RM in the strength of associations with walking, chair rising and stair climbing, was not confirmed.

The authors have no conflicts of interest to declare.

REFERENCES

1. Vincent KR, Vincent HK. Resistance exercise for knee osteoarthritis. PM R 2012; 4: 45–52.
2. Bartholdy C, Juhl C, Christensen R, Lund H, Zhang W, Henriksen M, editors. The role of muscle strengthening in exercise therapy for knee osteoarthritis: a systematic review and meta-regression analysis of randomized trials. Semin Arthritis Rheum 2017; 47: 9–21.
3. Nur H, Sertkaya BS, Tuncer T. Determinants of physical functioning in women with knee osteoarthritis. Aging Clin Exp Res 2018;30: 299–306.
4. ACSM's guidelines for exercise testing and prescription: Lippincott Williams & Wilkins; 2013.

5. Grgic J, Lazinica B, Schoenfeld BJ, Pedisic Z. Test–retest reliability of the one-repetition maximum (1RM) strength assessment: a systematic review. Sports Med Open 2020; 6 (1): 1–16.
6. Byrne C, Faure C, Keene DJ, Lamb SE. Ageing, muscle power and physical function: a systematic review and implications for pragmatic training interventions. Sports Med 2016; 46: 1311–1332.
7. Van der Esch M, Steultjens M, Knol D, Dinant H, Dekker J. Joint laxity and the relationship between muscle strength and functional ability in patients with osteoarthritis of the knee. Arthritis Care Res (Hoboken) 2006; 55: 953–959.
8. Van der Esch M, Steultjens M, Harlaar J, Knol D, Lems W, Dekker J. Joint proprioception, muscle strength, and functional ability in patients with osteoarthritis of the knee. Arthritis Care Res (Hoboken) 2007; 57: 787–793.
9. Kean CO, Birmingham TB, Garland SJ, Bryant DM, Giffin JR. Minimal detectable change in quadriceps strength and voluntary muscle activation in patients with knee osteoarthritis. Arch Phys Med Rehabil 2010; 91: 1447–1451.
10. Brzycki M. Strength testing – predicting a one-rep max from reps-to-fatigue. JOPERD 1993; 64: 88–90.
11. Steffen TM, Hacker TA, Mollinger L. Age-and gender-related test performance in community-dwelling elderly people: Six-Minute Walk Test, Berg Balance Scale, Timed Up & Go Test, and gait speeds. Phys Ther 2002; 82: 128–137.
12. Piva SR, Fitzgerald GK, Irrgang JJ, Bouzubar F, Starz TW. Get up and go test in patients with knee osteoarthritis. Arch Phys Med Rehabil 2004; 85: 284–289.
13. Fitzgerald GK, Piva SR, Irrgang JJ. Reports of joint instability in knee osteoarthritis: its prevalence and relationship to physical function. Arthritis Care Res (Hoboken) 2004; 51: 941–946.
14. Bellamy N, Buchanan WW, Goldsmith CH, Campbell J, Stitt LW. Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee. J Rheumatol 1988; 15: 1833–1840.
15. Roorda L, Jones C, Waltz M, Lankhorst G, Bouter L, Van der Eijken J, et al. Satisfactory cross cultural equivalence of the Dutch WOMAC in patients with hip osteoarthritis waiting for arthroplasty. Ann Rheum Dis 2004; 63: 36–42.
16. Stel VS, Smit JH, Pluijm SM, Visser M, Deeg DJ, Lips P. Comparison of the LASA Physical Activity Questionnaire with a 7-day diary and pedometer. J Clin Epidemiol 2004; 57: 252–258.
17. de Zwart AH, Dekker J, Roorda LD, et al. High-intensity versus low-intensity resistance training in patients with knee osteoarthritis: A randomized controlled trial. Clinical Rehabilitation. 2022; 36(7): 952–967. doi:10.1177/02692155211073039