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ORIGINAL ARTICLE

Hand-held dynamometry fixated with a tripod is reliable for assessment of back extensor strength in women with osteoporosis

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Abstract
Summary An appropriate method to assess back extensor strength in clinical practice has not yet been described. Our results showed that a hand-held dynamometry fixated with a tripod is reliable for assessing back extensor strength in women with osteoporosis.
Introduction Back strengthening exercises play an important role in the rehabilitation of patients with osteoporotic vertebral fractures. Evaluation of the effect of back strengthening exercises requires a method suitable for use in clinical practice to measure back extensor strength. A hand-held dynamometer (HHD) is quick and easy to handle in clinical practice. Currently, there is a lack of evidence whether a HHD is reliable for assessment of back extensor strength in people with osteoporosis. When using a HHD, it may be difficult for the tester to provide a counter pressure corresponding to the effort of the patient. In order to accommodate this, we have developed a tripod and a belt system, which was used to fixate the HHD. This study examined the intra-tester reliability of back extensor strength assessment in women with osteoporosis using a HHD.
Methods Back extensor strength of the participants was measured on two events with 7-day intervals. Test procedures were standardized, and all tests were performed by the same tester.
Results Forty-eight women with osteoporosis and vertebral fractures were included in the analysis. The coefficient of variation was 22 % using a HHD fixated by the tester and 17 % using a HHD fixated with the tripod. ICC was 0.75 (95 % confidence interval (CI), 0.63 and 0.88) when using a HHD with fixated by the tester and 0.90 (95 % CI, 0.84 and 0.95) when using a HHD fixated with the tripod.
Conclusion A HHD fixated with a tripod is reliable for the assessment of back extensor strength in women with osteoporosis and vertebral fractures.

Keywords Assessment · Back extensor strength · Hand-held dynamometer · Osteoporosis · Vertebral fractures

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Introduction

Vertebral fractures are claimed to be the most common clinical manifestation of osteoporosis [1]. Vertebral fractures and reduced back extensor strength can result in increased spinal kyphosis [2].

Increased kyphosis is associated with reduced physical function [3, 4], quality of life [5–7] and lung function [8] as well as an increased risk of falls [9–11]. Back extensor strength is believed to have significant influence on the degree of kyphosis [12]. Studies have indicated that women with osteoporosis have lower back extensor strength compared with non-osteoporotic women [2, 13, 14]. Moreover, there is a correlation between kyphosis and back extensor strength [15–17]. Several studies found that back extensor strength training was associated with a reduction in kyphosis [18, 19], improved balance [20, 21] and reduction of vertebral fractures [22, 23]. Training of back extensors thus plays an important role in the prevention of fractures [12].

To evaluate, monitor and document the effect of back extensor exercises in clinical practice, a method with a minimal risk of fracture or overload is needed [24]. In women with osteoporosis, back extensor strength is usually assessed isometrically using permanent strain gauge installations [1, 24, 25]. However, permanent installations are expensive and time-consuming and thus primarily used for research purposes [26].

An alternative to the permanent installation is a hand-held dynamometer (HHD). A HHD is a relatively inexpensive and time-saving solution attractive for use in clinical practice [26].

Two systematic reviews concluded that a HHD is a reliable and valid tool for assessing muscle strength in the extremities [27, 28]. Evidence on a HHD used for assessment of back extensor strength is sparse [29] and has poor reliability [29].

When using a HHD, it is difficult for the tester to provide a counter pressure corresponding to the effort of the patient [28], especially when measuring larger muscle groups. The tester can either provide too little or too much resistance resulting in too low or too high measurements [26]. To avoid this, the dynamometer can be fixed with belts. Use of external fixation can reduce measurement errors compared to assessments where the tester is fixating the HHD manually [30, 31]. The disadvantage of using external fixation of the HHD is however that it is not equally well suited for use in clinical practice [26]. This can be remedied by having a set-up that requires minimal extra equipment and time [26].

The aim of this trial was to identify measurement error and reliability of maximal isometric back extensor strength using a HHD in women with osteoporosis and vertebral fractures. Measurement error and reliability are covered both for assessment of HHD fixated by the tester and of HHD fixated with a tripod and a belt system.

Methods

Participants

The participants of this study are women above 50 years receiving standard medical treatment for osteoporosis. Inclusion criteria: minimum of one radiologically verified low-energy vertebral fracture with height loss of at least 20 % of the front of the corpora and persistent back pain for at least 3 months prior to baseline. Exclusion criteria: severe exacerbation of back pain within 6 weeks prior to baseline, new onset of radiologically verified fractures or major comorbidities such as malignancy of the spine. According to literature, the study population in a reliability study should consist of at least 50 persons [32]. As power calculations are not made in this type of study, we used experiences from a previous study where half of the invited accepted to participate in the study [33]. Thus, to ensure proper statistical power of the current study, we invited 118 women to participate.

Sixty-one (52 %) gave written consent to participate. Five did not meet the inclusion criteria; another five were excluded: one due to illness in the family, one due to newly emerged costae fracture, one due to illness and two due to inability to perform the tests. Fifty-one women completed the first test day. Two of these women did not complete the test on day 2: one due to illness and one due to worsening of back pain after the first test; 49 women completed both tests. One woman was excluded from the analysis as she used asthma medication immediately before assessment with HHD fixated on test day 2. After taking asthma medication, she performed markedly better than all the other test trials. To avoid confusion, this participant was excluded from all analyses. A total of 48 participants were included in the final analysis.

Data collection

The project was approved by The Danish Data Protection Agency. The Regional Scientific Ethics Committee stated that the project did not need approval. All investigations were in accordance to the protocol and followed the ethical and humane principles of research. Information on participants' number of vertebral fractures and bone mineral density (BMD) in the spine was obtained from medical records and radiographs.

Test set-up

Participants were tested at two events with a 7-day interval at the same time of day. It was assumed that strength does not change during this short period. All muscle strength tests were performed by the same tester experienced in the use of a HHD. The same assessment equipment and sequence of measurements was used on both test days. On the second test day, the tester was blinded to the test results from day 1. Back extensor strength was measured with a HHD (Power Track II commander). Test procedures were standardized, and the dynamometer was calibrated before each test. For external fixation, we used a lightweight aluminium tripod and the dynamometer load cell was mounted on a box. The tripod with the load cell was fixated using two belts. To make the test set-up stable, a sheet was placed between the participant's back and the load cell of the HHD (Fig. 2).

Test procedure

Each test was initiated by a 2-min warm up of the back extensor muscles; the test person was sitting on a couch (plinth) with her back straight, arms along the body and palms facing backward. From this starting position, the test person was asked to outwardly rotate the upper limb so that the palms pointed towards the ceiling and to pull her shoulder blades together. The test position and number of repetitions were based on literature recommendations [24]. During the test, the participant was positioned on the couch with feet over the edge piece (5 cm from the malleol to tile edges). Hip and knee were in neutral position, and arms were extended and palms pointing upwards. The load cell was placed on the midline between the two anguli superior to scapulae (Fig. 1).

Fig. 1 Assessing back extensor strength using HHD fixated by the tester

The participants were given the following instructions before each test:

"In a little while when I say, lift the arms from the couch, and when I say go ahead, lift your head from the couch and push back against my hand, as hard as you can. I say push, push, push, push and relax".

To reduce the impact of a possible learning effect, a warm up test trial was performed followed by three test trials of 5 s. There was a 60-s pause between each test trial. If the last measurement was more than 5 % higher than the previous measurement, an additional test was made to ensure that the highest possible value had been achieved [24].

After three test trials, the participants were given a 5-min break. Subsequently, the procedure was repeated with the HHD fixated with the tripod (Fig. 2).

Fig. 2 Assessing back extensor strength using HHD fixated with a tripod and a belt system

Reliability

We tested the statistical hypothesis that back extensor strength assessments using a HHD are intra-tester reliable and that assessment using a HHD fixated with a tripod increased reliability compared with a HHD fixated by the tester. Terminology and statistical measurements of reliability in the article follow recommendations from the COSMIN group [34]. The most important measurement was standard error of measurement (SEM) and relative SEM or the coefficient of variation (CV) and the intra-class correlation (ICC). According to the literature, a CV below 20 % was considered acceptable in this population [19, 25, 35]. An ICC≥0.90 is required for clinical application to ensure valid interpretation of findings [36].

Statistical analysis

Clinical characteristics were presented as mean±SD. Results from muscle strength tests are displayed with Bland-Altman plots where the differences between tests are plotted against the average of the two tests. A paired *t* test was used to test for systematic differences between test 1 and test 2. SEM was calculated to identify the degree of random variation (SEM = SD/√2) and 95 % confidence intervals and limits of agreement were calculated from the Bland-Altman plots. Smallest detectable change (SDC) was calculated (SEM × 1.96 × √ 2).

The CV was calculated as SEM on a log scale. To evaluate reliability, ICC (1.2), with a corresponding 95 % confidence intervals, was calculated. For all statistical tests, a significance level of 5 % was used.

All analyses were performed in STATA 12.

Results

Clinical characteristics of the participants are presented in Table 1.

Figure 3a, b illustrates the averages of the two measurements for HHD tester fixated and HHD tripod fixated, respectively plotted against the absolute differences between the two measurements. The solid red lines illustrate the limits of

Table 1 Clinical characteristics of the 48 participants

Characteristics	Mean (SD)
Age (years)	72 (9.3)
Weight (kg)	63.4 (9.4)
Current height (cm)	167 (6.0)
Height reduction (cm)[a]	3.3 (2.9)
T-score spine	−2.3 (1.2)
T-score hip	−1.69 (0.92)
Vertebral fractures[b]	2.1 (1.7)
Participants with	N (%)
Thoracic fractures only	30 (62)
Lumbar fractures only	6 (13)
Vertebral+lumbar fractures	10 (21)
Missing	2 (4)

Continuous data are expressed as mean and SD. Category data are expressed as numbers and percent

[a] Difference between current height and height in passport

[b] Number of radiologically verified vertebral fractures

agreement (LOA) for the two fixation methods. Assessments with a HHD fixated by a tester resolved in a greater variety of differences than assessments using a HHD fixated with a tripod.

Measurement error and reliability of the back extensor strength assessments are presented in Table 2. Measurement error is divided into systematic error and random error. When using a HHD fixated by a tester, a systematic error of 8 N was observed, while using a HHD fixated with the tripod showed a systematic error of -0.9 N. None of the systematic errors were statistically significant. SEM and CV represent the random error; CV was 22 % using a HHD fixated by a tester and 17 % using a HHD fixated with the tripod. ICC was 0.75 when using a HHD fixated by the tester and 0.90 when using a HHD fixated by the tripod.

Discussion

Summary of main findings

Our results showed that a HHD fixated with a tripod is intra-tester reliable for assessing back extensor strength in women with osteoporosis and vertebral fractures. When using a HHD fixated with a tripod, both an acceptable degree of measurement error and reliability was achieved. This was not the case when using a HHD fixated by the tester where neither an acceptable level of measurement error nor an acceptable level of reliability was achieved.

The mean back extensor strength was approximately 10 N higher using HHD fixated with the tripod compared to HHD fixated by tester. This difference between the two fixation methods may question the validity of back extensor strength assessments when using a HHD fixated by a tester.

The results of our study showed that when using a HHD to assess back extensor strength, a HHD fixated with a tripod was superior. This may be thought of as a bit of a paradox since the benefits of using a HHD rather than permanent set-ups is that it is quick and easy to apply in clinical practice. However, the experience from our study was that external fixation with the tripod was easy to assemble and use. Thus, a HHD fixated with a tripod can be used in clinical practice without compromising the practical applicability.

Study population

The study population consisted of women with manifest osteoporosis. The participants mean T-score for both spine and hip was, however, higher than −2.5, indicating osteopenia rather than osteoporosis (Table 1). The relatively high BMD was most likely due to the fact that all participants were taking osteoporosis medication.

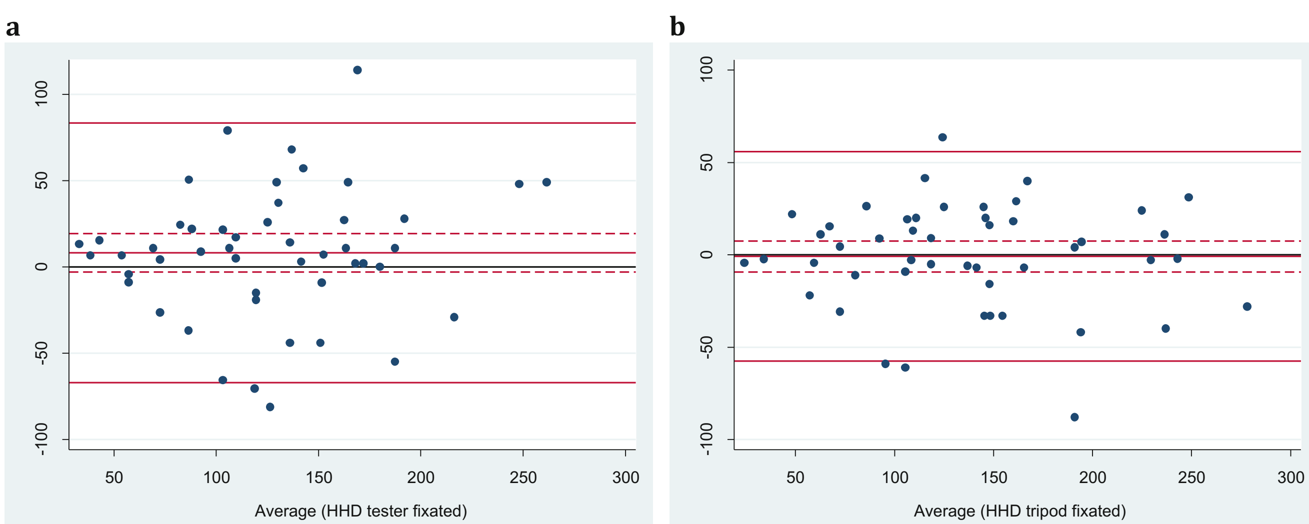

Fig. 3 **a** Bland-Altman plot HHD tester fixated. **b** Bland-Altman plot HHD tripod fixated

Table 2 Measurement error and reliability of back extensor strength assessment

Fixation type	Test 1 (N)[a]	Test 2 (N)[a]	Diff[a,b]	p value	SEM	CV (%)	ICC (95 % CI)	SDC
Tester fixated	130.3 (57.6)	122.2 (52.7)	8.1 (38.4)	0.15	27.1	22	0.75 (0.63, 0.88)	75.2
Tripod fixated	135.7 (61.5)	136.6 (63.7)	−0.9 (28.9)	0.83	20.5	17	0.90 (0.84, 0.95)	56.7

[a] Data are presented as mean (SD)

[b] Test 1–test 2

The testing position (lying supine) could potentially be a challenge for people with osteoporosis due to the hyper-kyphosis. In our study, hyper-kyphosis did not act as a barrier to perform the test. Only two women were not able to perform the test, one due to dyspnoea when lying supine and one did not have strength in the back extensors to lift her head free from the couch. An advantage when using tripod fixation was the tripods ability to tilt insuring full contact between the patients back and the load cell of the HHD even when substantial hyper-kyphosis was present.

Measurement errors in clinical practice

It is often discussed in the reliability literature at what confidence limits clinical measures should be interpreted. We used SEM and CV to illustrate the expected variation between two tests if there was a change in muscle strength between tests. According to Atkinson et al., this interpretation of the terms is not quite adequate as SEM and CV only describe the variation in 68 % of the cases [37]. LOA and SDC cover the random error between tests in 95 % of the cases [37–39]. Atkinson et al. argue that by applying CV as a measure of the random error, it is likely to underestimate the true variation when new individuals are tested [37]. Hopkins et al. argue, however, that the use of 95 % confidence interval such as LOA and SDC are too restrictive and that the range is often too broad to be used in clinical practice to assess whether there has been a change in, for example, muscle strength between two tests [39]. According to Hopkins et al., use of 95 % confidence intervals can cause practitioners to ignore clinically relevant changes and thereby refrain from taking clinically important decisions concerning rehabilitation [39].

In this project, we used SEM and CV to express the random error as recommended by Hopkins et al. The results of LOA and SDC are also shown to give the reader more perspectives on the reliability of assessments in a given clinical situation.

Comparison with other trials

As mentioned in the introduction, only one study investigating use of a HHD for assessing back extensor strength was identified [29]. In this trial by Moreland et al., the inter-tester reliability was investigated. The results were a statistically significant systematic variation between tests and a low correlation of only 0.24 [29]. There may be several explanations for the low level of inter-tester reliability in this study. One might be the test position where the participants were lying on a couch with the upper body beyond the edge of the couch which makes it difficult for the participants to perform the test and for the tester to stabilize the dynamometer. Moreover, the tests were performed by three different testers, further contributing to the variation between measurements.

In our study, the test position and number of repetitions followed recommendations by Limburg et al. [24]. Limburg et al. examined reliability using strain gauges (permanent test set-up). The result was a CV of 2.33 % [24]. The method used to calculate the CV is not described in the article, and there are several available methods. It must however be assumed that the CV in the trial by Limburg et al. was lower than what we found in our study. The results of our trial suggest that the CV is lower in people with high back extensor strength and no back pain compared to those with low muscle strength and back pain (data not shown). Limburg et al. used a study population of 13 young physically active men and women [24]. The average back extensor strength at test 1 in the trial by Limburg et al. was 461 N compared to 136 N in our study. Among women in our study, with an average back extensor strength above 200 N, a CV of 8 % was observed (using a HHD fixated with the tripod). This suggests that the different results in the two studies may be due to differences in study population and not that assessing muscle strength using permanent test set-ups are more accurate.

Strengthening of back extensors plays an important role in the prevention of vertebral fractures and in the rehabilitation of people with osteoporosis. Currently, there is no tradition of assessing back extensor strength in clinical practice. One explanation is probably that an appropriate method to measure back extensor strength in clinical practice has not yet been described. The one trial examining the use of a HHD for assessment of back extensor strength failed to demonstrate that a HHD was suitable for assessing back extensor strength [29]. Our study indicates, however, that a HHD fixated by a tripod can be used in both clinical practice and research to assess, monitor and document the effect of back extensor exercises in women with osteoporosis and vertebral fractures.

Conclusion

Use of a HHD fixated with a tripod and a belt system improved intra-tester reliability in comparison to the use of a HHD fixated by the tester. When using a HHD fixated with a tripod, a CV of less than 20 % and an ICC of 0.90 were achieved, resulting in an acceptable level of measurement error and reliability. It is thus concluded that the HHD fixated with a tripod is intra-tester reliable for assessing back extensor strength in women with osteoporosis and vertebral fractures.

Conflicts of interest None.

References

1. Miyakoshi N, Hongo M, Maekawa S, Ishikawa Y, Shimada Y, Itoi E (2007) Back extensor strength and lumbar spinal mobility are predictors of quality of life in patients with postmenopausal osteoporosis. Osteoporos Int 18:1397–1403
2. Granito RN, Aveiro MC, Renno AC, Oishi J, Driusso P (2012) Comparison of thoracic kyphosis degree, trunk muscle strength and joint position sense among healthy and osteoporotic elderly women: a cross-sectional preliminary study. Arch Gerontol Geriatr 54:e199–e202
3. Leidig-Bruckner G, Minne HW, Schlaich C, Wagner G, Scheidt-Nave C, Bruckner T, Gebest HJ, Ziegler R (1997) Clinical grading of spinal osteoporosis: quality of life components and spinal deformity in women with chronic low back pain and women with vertebral osteoporosis. J Bone Miner Res 12:663–675
4. Ryan SD, Fried LP (1997) The impact of kyphosis on daily functioning. J Am Geriatr Soc 45:1479–1486
5. Cortet B, Houvenagel E, Puisieux F, Roches E, Garnier P, Delcambre B (1999) Spinal curvatures and quality of life in women with vertebral fractures secondary to osteoporosis. Spine (Phila Pa 1976) 24: 1921–1925
6. van Schoor NM, Smit JH, Twisk JW, Lips P (2005) Impact of vertebral deformities, osteoarthritis, and other chronic diseases on quality of life: a population-based study. Osteoporos Int 16:749–756
7. Hallberg I, Rosenqvist AM, Kartous L, Lofman O, Wahlstrom O, Toss G (2004) Health-related quality of life after osteoporotic fractures. Osteoporos Int 15:834–841
8. Schlaich C, Minne HW, Bruckner T, Wagner G, Gebest HJ, Grunze M, Ziegler R, Leidig-Bruckner G (1998) Reduced pulmonary function in patients with spinal osteoporotic fractures. Osteoporos Int 8: 261–267
9. Lynn SG, Sinaki M, Westerlind KC (1997) Balance characteristics of persons with osteoporosis. Arch Phys Med Rehabil 78:273–277
10. Ishikawa Y, Miyakoshi N, Kasukawa Y, Hongo M, Shimada Y (2009) Spinal curvature and postural balance in patients with osteoporosis. Osteoporos Int 20:2049–2053
11. Ishikawa Y, Miyakoshi N, Kasukawa Y, Hongo M, Shimada Y (2012) Spinal sagittal contour affecting falls: cut-off value of the lumbar spine for falls. Gait Posture
12. Sinaki M (2012) Exercise for patients with osteoporosis: management of vertebral compression fractures and trunk strengthening for fall prevention. PM R 4:882–888
13. Sinaki M, Wollan PC, Scott RW, Gelczer RK (1996) Can strong back extensors prevent vertebral fractures in women with osteoporosis? Mayo Clin Proc 71:951–956
14. Mika A, Unnithan VB, Mika P (2005) Differences in thoracic kyphosis and in back muscle strength in women with bone loss due to osteoporosis. Spine (Phila Pa 1976) 30:241–246
15. Sinaki M, Limburg PJ, Wollan PC, Rogers JW, Murtaugh PA (1996) Correlation of trunk muscle strength with age in children 5 to 18 years old. Mayo Clin Proc 71:1047–1054
16. Ettinger B, Black DM, Nevitt MC, Rundle AC, Cauley JA, Cummings SR, Genant HK (1992) Contribution of vertebral deformities to chronic back pain and disability. The Study of Osteoporotic Fractures Research Group. J Bone Miner Res 7:449–456
17. Miyakoshi N, Hongo M, Maekawa S, Ishikawa Y, Shimada Y, Okada K, Itoi E (2005) Factors related to spinal mobility in patients with postmenopausal osteoporosis. Osteoporos Int 16: 1871–1874
18. Pfeifer M, Sinaki M, Geusens P, Boonen S, Preisinger E, Minne HW, ASBMR Working Group on Musculoskeletal Rehabilitation (2004) Musculoskeletal rehabilitation in osteoporosis: a review. J Bone Miner Res 19:1208–1214
19. Pfeifer M, Begerow B, Minne HW (2004) Effects of a new spinal orthosis on posture, trunk strength, and quality of life in women with postmenopausal osteoporosis: a randomized trial. Am J Phys Med Rehabil 83:177–186
20. Pfeifer M, Kohlwey L, Begerow B, Minne HW (2011) Effects of two newly developed spinal orthoses on trunk muscle strength, posture, and quality-of-life in women with postmenopausal osteoporosis: a randomized trial. Am J Phys Med Rehabil 90:805–815
21. Sinaki M, Brey RH, Hughes CA, Larson DR, Kaufman KR (2005) Balance disorder and increased risk of falls in osteoporosis and kyphosis: significance of kyphotic posture and muscle strength. Osteoporos Int 16:1004–1010
22. Sinaki M, Itoi E, Wahner HW, Wollan P, Gelzcer R, Mullan BP, Collins DA, Hodgson SF (2002) Stronger back muscles reduce the incidence of vertebral fractures: a prospective 10 year follow-up of postmenopausal women. Bone 30:836–841
23. Borgo M, Sinaki M (2010) Back progressive resistive exercise program to reduce risk of vertebral fractures. J Mineralstoffwechsel 17: 66–71
24. Limburg PJ, Sinaki M, Rogers JW, Caskey PE, Pierskalla BK (1991) A useful technique for measurement of back strength in osteoporotic and elderly patients. Mayo Clin Proc 66:39–44
25. Hongo M, Itoi E, Sinaki M, Miyakoshi N, Shimada Y, Maekawa S, Okada K, Mizutani Y (2007) Effect of low-intensity back exercise on quality of life and back extensor strength in patients with osteoporosis: a randomized controlled trial. Osteoporos Int 18:1389–1395
26. Bandholm T, Thorborg K (2010) Måling af muskelstyrke i klinisk praksis. Fysioterapeuten Årg. 92, nr. 12 (2010):10-12 14-20
27. Stark T, Walker B, Phillips JK, Fejer R, Beck R (2011) Hand-held dynamometry correlation with the gold standard isokinetic dynamometry: a systematic review. PM R 3:472–479
28. Kolber MJ, Cleland JA (2005) Strength testing using hand-held dynamometry. Phys Ther Rev 10:99–112
29. Moreland J, Finch E, Stratford P, Balsor B, Gill C (1997) Interrater reliability of six tests of trunk muscle function and endurance. J Orthop Sports Phys Ther 26:200–208
30. Thorborg K, Bandholm T, Holmich P (2013) Hip- and knee-strength assessments using a hand-held dynamometer with external belt-fixation are inter-tester reliable. Knee Surg Sports Traumatol Arthrosc 21:550–555
31. Kramer JF, Vaz MD, Vandervoort AA (1991) Reliability of isometric hip abductor torques during examiner- and belt-resisted tests. J Gerontol 46:M47–M51
32. Mokkink LB, Terwee CB, Patrick DL, Alonso J, Stratford PW, Knol DL, Bouter LM, de Vet HC (2010) The COSMIN checklist for assessing the methodological quality of studies on measurement

properties of health status measurement instruments: an international Delphi study. Qual Life Res 19:539–549
33. Valentin GH, Pedersen LN, Maribo T (2013) Wearing an active spinal orthosis improves back extensor strength in women with osteoporotic vertebral fractures. Prosthet Orthot Int
34. Mokkink LB, Terwee CB, Patrick DL, Alonso J, Stratford PW, Knol DL, Bouter LM, de Vet HC (2010) The COSMIN study reached international consensus on taxonomy, terminology, and definitions of measurement properties for health-related patient-reported outcomes. J Clin Epidemiol 63:737
35. Sinaki M, Brey RH, Hughes CA, Larson DR, Kaufman KR (2005) Significant reduction in risk of falls and back pain in osteoporotic-kyphotic women through a Spinal Proprioceptive Extension Exercise Dynamic (SPEED) program. Mayo Clin Proc 80:849–855
36. Innes E, Straker L (1999) Reliability of work-related assessments. Work 13:107–124
37. Atkinson G, Nevill AM (1998) Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. Sports Med 26:217–238
38. Weir JP (2005) Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. J Strength Cond Res 19:231–240
39. Hopkins WG (2000) Measures of reliability in sports medicine and science. Sports Med 30:1–15