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Systematic Review

# Appraising the Validity of Tools to Measure Multijoint Leg Power: A Systematic Review

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**KEYWORDS**
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**Abstract** *Objective:* To critically appraise the validity of tools used to measure maximum multijoint leg extension power in older individuals.
*Data Sources:* A systematic literature search was performed in 5 electronic databases: PUBMED, EMBASE, CINAHL, SPORTDISCUS, and PEDRO from inception and without limits on the year of publication. Secondary searches included hand searching of the reference lists.
*Study Selection:* One author performed all the searches and identified relevant studies. A second author repeated the search to ensure that no articles were overlooked. Only studies that measured multijoint leg extension power were included. Those that used jump tests on force plates were excluded. Forty-five studies were identified that used 3 different tools. Three of these studies addressed the validity of the instruments and were included in the analyses performed by all the authors. Decisions made by consensus.
*Data Extraction:* Critical analyses were based on the reference instrument used, reproducibility of methods, appropriateness of the statistical analysis, commercial availability of the tool, and potential conflicts of interests, including financial support. Decisions regarding the data analyses were made by consensus among all authors.
*Data Synthesis:* We identified 3 tools all of which simulated recumbent bicycles. Two of the 3 identified tools are not commercially available. Each of the 3 included studies used correlational analysis to determine the validity of their tool, which does not describe the accuracy of the measured power in comparison to the reference standard.
*Conclusion:* We were unable to identify a validated tool that measured maximum multijoint leg extension power that was appropriate for older individuals. Future research should address this important gap.


*List of abbreviations:* ADL, activities of daily living.
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Strength and power of skeletal muscles enable functional movement. Muscle strength is the force developed during voluntary contraction against a resistance,[1] whereas power is the product of that force and the velocity of muscle contraction.[2] Literature has shown that muscle mass declines by as much as 40% between the second and seventh decades of life.[3] The decline in muscle mass is due to a significant reduction of both the size and number of Type I and Type II muscle fibers, with the Type II fibers being preferentially affected.[4] This decline in muscle mass leads to a reduction in muscular strength and power.[4] Studies have reported a decline in muscle strength and power at a rate of 1%-2% per year and 3%-4% per year, respectively, after the third decade of life.[5] These lead to mobility limitations in the elderly.[6]

Mobility limitations are a major concern in an aging population. They include difficulty or inability to perform basic activities of daily living (ADL) like rising from chair, climbing a flight of stairs, or walking several city blocks.[6] Traditionally, muscle strength was considered the primary predictor of physical function and its decline was an important factor limiting function in the elderly. However, studies now suggest that muscle power is the key factor determining physical function.[2,5-9] In community-dwelling older adults, leg muscle power is a strong independent predictor of physical function[3,10] and self-reported difficulties in performing ADL.[9] Studies have also reported leg muscle power, compared to strength, to be a better predictor of ADL like rising from a chair.[11,12] Hence, the age-related decline in muscle power needs to be addressed to optimize independent physical functioning in elderly.

Rehabilitation to slow this age-related decline in function in the elderly depends on being able to prescribe power-based lower extremity exercises. A number of functional tests, most notably the sit-to-stand test[13-15] and the stair climbing power test,[16-18] have been proposed as simple, valid methods of assessing power in older individuals. Many factors affect conclusions about the validity of these tools. For instance, variability of the seat height and the prescribed duration or number of rises in the test affect the outcome in the sit-to-stand test.[19] A landmark study by Lord et al[14] concluded that quadriceps strength was the most important variable determining sit-to-stand times, but other factors such as proprioception, balance, and vision accounted for more than half the explained variance. Most studies have validated the sit-to-stand test using measures of strength. However, Hardy et al[15] assessed the relation between performance of the 10-time sit-to-stand test and lower extremity power and standing balance. Balance was a significant predictor of test performance and the investigators cautioned against using the test as proxy for leg power.[15] Lindemann et al[20] reported a poor correlation between lower extremity power and the 5-time sit-to-stand set.[20] The stair climbing power test assesses power that can be quantified in Watts. Interestingly, most validation studies for this test use lower extremity leg press strength as the comparator and do not control the velocity of the extension movement.[17,18,21,22] Cardiovascular and respiratory functions are known to influence stair climbing performance[23,24] as is balance.[16] The number of stairs climbed varies greatly among testing protocols and affects the outcome.[16] Thus, these functional tests provide a useful way to track change in performance over time, but they have not been shown to measure lower extremity extensor power directly nor do they assess maximum performance, which is the criterion standard for exercise prescription.

Investigations assessing multijoint leg extension power are not numerous.[5] Most instruments measure single joint movements that are used to represent whole leg extension power. However, functional activities like a chair rise involve multijoint leg extension and muscle power measured for any single joint (hip or knee) does not fully reflect this.[5] Jump tests on force plates have been used[25] to assess multijoint leg extension power; however, their use presents serious limitations in older populations where poor balance and osteoporosis may make jumping unsafe.[26]

Another crucial issue to consider is how validity of a tool is assessed. Typically, researchers use correlational analysis but more precise statistical analyses should be used when an instrument is to be used for exercise prescription. The Altman and Bland[27] test assesses the agreement between 2 measurement methods and gives an inference about whether one method is equal to, and can replace, the other.

## Objectives

The purpose of this systematic review is to critically appraise the validity of existing tools, excluding jump tests performed on force plates, that measure maximum multijoint leg extension power. We were particularly interested in tools that would be appropriate for older individuals.

## Methods

### Identification of studies and eligibility criteria

We included studies that assessed multijoint leg extensor power using different measurement instruments. Studies that examined muscle power for single joint movements of hip and knee separately were excluded as were studies that used jump tests performed on force plates.

### Information sources

We searched the following electronic databases: PUBMED, EMBASE, CINAHL, SPORTDISCUS, and PEDRO. When a search in 1 database returned 2 or more citations for an author, we performed specific author searches in all the remaining databases. We conducted independent searches with the names of instruments identified as measuring multijoint extension power (leg extensor power rig, servo-controlled dynamometer, Keiser pneumatic leg press). The authors (Bassey and Short) of 1 study[28] using an instrument fulfilling the purpose of the review were contacted to ask for detailed information regarding the study's methodology with respect to the validity of the instrument. It was not necessary to contact the authors of the other 2 studies because their papers provided sufficient information to evaluate the validity of their instruments. The original search for this review was performed on March 20, 2019 and was updated on May 22, 2020.

### Search strategy

The key search term used was hip knee extension power. No limits were placed on dates of publication and types of studies. No Boolean operators were used to narrow the results of the searches.

### Study selection

The first author (P.T.) performed all the searches, identified the relevant studies by titles, and then examined the abstracts of all the retrieved studies to determine if the studies met the inclusion criteria. The entire search was repeated by R.G. to ensure that no articles were missed. Next, P.T. examined the full text of all the studies measuring multijoint leg extension power for evaluation of the methodology used. After removing the studies that examined separate hip and knee movements, and jump tests on force plates, those examining multijoint leg extension movement were kept for further critical analysis pertaining to the validity of instrument. Last, P.T., R.G., and G.D. carried out the critical analysis of the included studies. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses supported the development of relevant components of this study.

### Data collection and assessment of included studies

All authors independently reviewed the full text of included studies and met to discuss the findings. Inclusion of the studies was determined via consensus. All authors contributed to data extraction and the critical appraisal of the included studies. Critical appraisal criteria were established, based on the principles of experimental design, to support the assessment of included studies.

Some of the studies that met the inclusion criteria did not clearly describe the methodology used to validate the instrument. In cases where we could not find this information through literature searches, the authors were contacted to ask for clarifications pertaining to their validation methodology.

### Data items

The following information was collected for each included study: the study design, the instrument used, the population size, the reference instrument used for validation, the statistical test used for validation, the results relevant to validity of instrument, and the author's conclusions (table 1).

## Results

### Study selection

The initial search of the 5 databases: PUBMED, EMBASE, CINAHL, SPORTDISCUS, and PEDRO, using search query *hip knee extension power* retrieved 725 results. Other searches in these databases using search queries *leg extensor power rig*, *servo-controlled dynamometer*, and *Keiser pneumatic leg press* to identify the validity of these instruments found during initial search gave 99, 18, and 24 results, respectively. Therefore, a total of 866 articles were obtained through these 5 databases. Fifteen additional studies were retrieved by hand searching of the reference lists. Figure 1 depicts the study selection process.

A total of 494 unique studies remained after removal of duplicates. Of these, 436 were excluded because, after reading the abstracts, we determined that the study did not address the research question. Four other studies were excluded because they used jump tests performed on force plates. The initial search was broad to ensure that article capture was comprehensive. The remaining 54 full-text studies were then screened for eligibility. A further 9 studies were excluded because they did not assess multijoint leg extension and instead assessed individual hip or knee joints and presented them as a representative of leg power. The remaining 45 full-text articles addressed the measurement of multijoint leg extension power. Five used the Keiser pneumatic leg press and 4 described a servo-controlled dynamometer. The remaining 36 articles published information about the leg extensor power rig. A total 42 of the 45 full-text articles were excluded because they did not give information on instrument validation. Three studies met the review criteria and were included for further analysis.

### Study characteristics

Studies included in this review examined 3 instruments: the leg extensor power rig,[28,a] a servo-controlled dynamometer,[29,b] and the Keiser pneumatic leg press machine.[30,c] The leg extensor power rig developed by Bassey and Short[28] measures the average power generated by the lower limb muscles during a single leg extensor thrust against a pedal, which, in turn, accelerates a flywheel. It does not measure the maximum leg extensor power. The researchers who developed this instrument compared the average leg muscle power measured using their device against that from an isokinetic dynamometer in 16 participants (mean age: 27±7.5y). They used Spearman's ranked correlation test and reported the power calculated by the 2 instruments to be significantly correlated ($\rho=0.82$, $P<.001$). Bassey and Short also compared leg muscle power calculated using the leg extensor power rig against that derived from a jump test on a force plate. Force plates are laboratory instruments that are considered to be the criterion standard to measure multijoint leg extension power.[31] The investigators compared the power in 13 participants (mean age: 39±10.4y) using Spearman ranked correlation coefficient test. Again, they found the 2 measurements to be significantly correlated ($\rho=0.86$, $P=<.001$). Based on these results, Bassey and Short concluded that the power rig was a valid tool to measure leg extension power. The servo-controlled dynamometer developed by Yamauchi et al[32] measures peak leg extension power. It is an instrument similar to a leg press machine where a participant pushes the footplate using both the legs and the force

**Table 1** Summary of included studies

| Study | Study Design | Instrument Used | Reference Instrument | Sample Size | Statistical Test Used for Validation | Study Results | Author's Conclusions |
|---|---|---|---|---|---|---|---|
| Thomas et al[30] | Comparative study | Keiser pneumatic double leg press machine | Leg extensor power rig | n=19 | Rank-ordered correlation | $\rho=0.565$, $P<.016$ | Based on the correlation with the power rig, the Keiser leg press is a valid tool to measure multijoint leg extension power. |
| Yamauchi and Ishii[29] | Comparative study | Servo-controlled dynamometer | Jump gauge | n=67 | Pearson product-moment correlation coefficient test | $r=0.76$, $P=<.001$ | The servo-controlled dynamometer can estimate power of knee-hip extension movements and can evaluate the multijoint movement of the lower limbs. |
| Bassey and Short[28] | Comparative study | Leg extensor power rig | 1. Isokinetic dynamometer 2. Force plates (Kistler) | 1. n=16 2. n=13 | 3. Spearman ranked correlation coefficient test 4. Spearman ranked correlation coefficient test | 1. $\rho=0.82$, $P=<.001$ 2. $\rho=0.86$, $P=<.001$ | Based on significant correlations with the isokinetic dynamometer and the force plates, the power rig is a valid method for measuring leg power. |

NOTE. Bassey and Short[28] compared their results of leg muscle power measured using the leg extensor power rig against that from (1) an isokinetic dynamometer in 16 participants and (2) a jump test on a force plate in 13 participants.

during the movement is controlled using a servo motor. Yamauchi and Ishii[29] compared the leg muscle power measured using the servo-controlled dynamometer with the vertical jump performance measured using the jump gauge.[d] The researchers used Pearson's correlation to compare the power from the 2 tests in 67 participants (mean age: 19.54±2y). They reported a strong significant correlation ($r=0.76$, $P=<.001$) and on that basis claimed the servo-controlled dynamometer was a valid tool to measure multijoint leg extension power. The Keiser pneumatic leg press[33] is a seated bilateral leg press machine that uses pneumatic resistance to measure leg extension power. Thomas et al[30] compared the leg muscle power measured using the Keiser pneumatic leg press with that from Bassey and Short's leg extensor power rig in 19 women (age range: 21-29y). Using rank-ordered correlation, they reported a moderately strong correlation ($\rho=0.565$, $P<.016$) between the 2 measures.

## Discussion

The purpose of this systematic review was to critically appraise validated tools that did not use jump tests performed on force plates to measure multijoint leg extension power. We identified 3 tools that claimed to provide valid assessments of multijoint leg extension power. Table 2 presents our assessment of the included studies. One of the 3 identified tools, the leg extensor power rig developed by Bassey and Short[28] was validated against leg extensor power assessed using an isokinetic dynamometer as well as vertical jump power measured on a force plates. The authors claimed that the dynamometer measured combined hip and knee extension; however, we are not aware of an isokinetic dynamometer that will do this. We contacted the investigators via email to ask about the dynamometer configuration but did not receive a reply. Therefore, we assumed the investigators used either hip or knee extension power to represent whole leg power. If this is the case, neither can accurately represent the multijoint leg extension power and hence the validity of the instrument cannot be ensured. As a part of their instrument validation, the authors also compared the power rig results with the force plate measured vertical jump power. However, the vertical jump is a 2-legged movement and the leg extensor power rig can only measure single-leg extension power. Hence, although there was moderate to strong correlation between the power rig results and power assessed using reference instruments, these methodology weaknesses make it difficult to accept the purported validity of leg extensor power rig in terms of its use for exercise prescription.

Another instrument, the servo-controlled dynamometer by Yamauchi et al,[32] was developed in Niigata, Japan. The researchers validated this instrument by comparing its results with the vertical jump performance measured on a jump gauge. The jump gauge gave the estimated height of

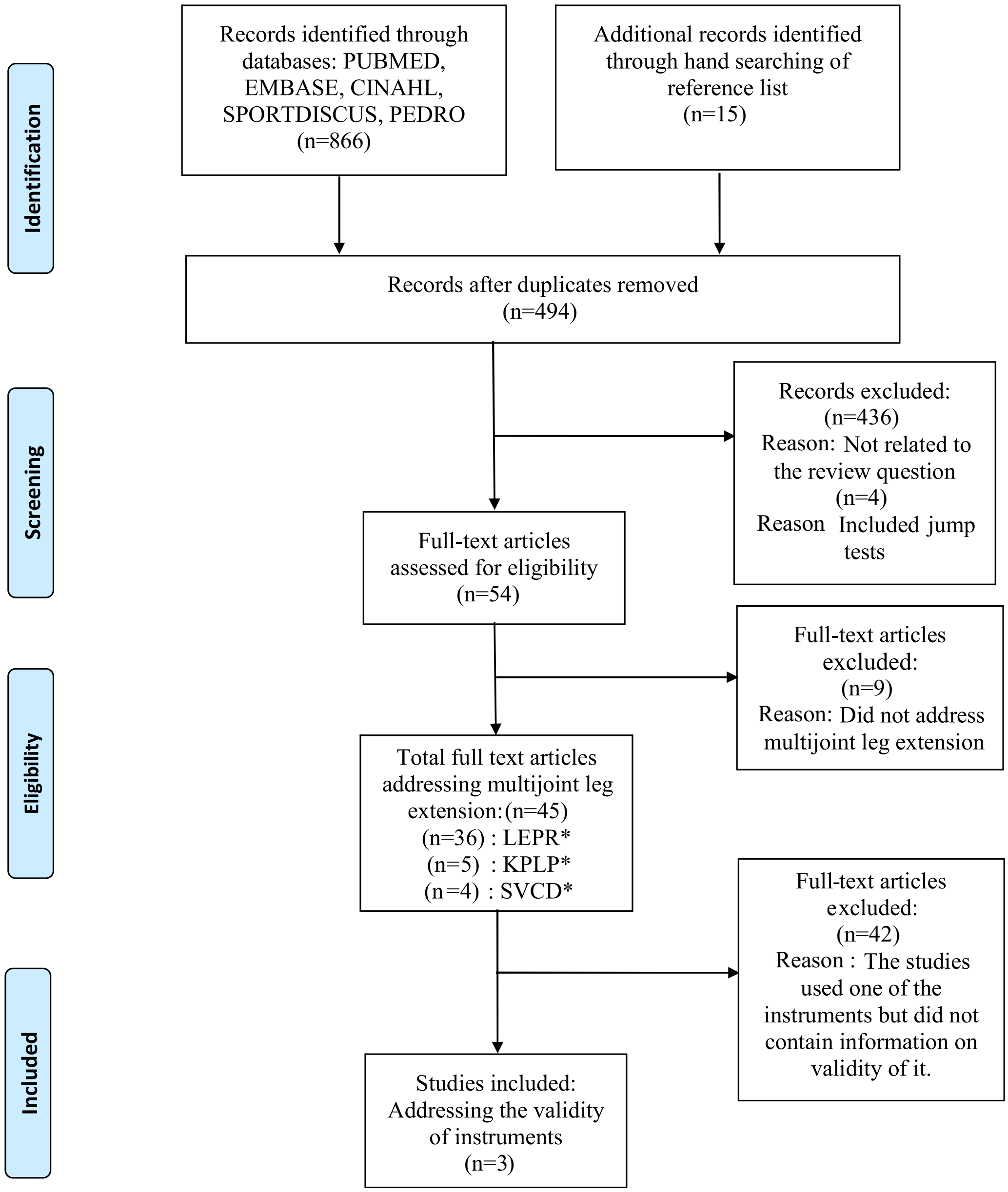


**Fig 1** PRISMA flow diagram for the systematic review identifying the databases searched, the number of titles, abstracts, and full-text articles reviewed as well as reasons for exclusion. Abbreviations: KPLP, Keiser pneumatic leg press machine; LEPR, leg extensor power rig; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; SVCD, servo-controlled dynamometer.

the vertical jump in centimeters, which was considered the jump performance. Although, the vertical jump performance might be related to the servo-controlled dynamometer measured leg power, this information is not enough to give us an understanding about accuracy of the servo-controlled dynamometer measured power. In addition, the authors did not provide information regarding the validity of the jump gauge used. Also, the servo-controlled dynamometer is not commercially available and therefore cannot be used in a clinical setting for exercise prescription.

The Keiser pneumatic leg press[30] was validated against the leg extensor power rig.[28] As noted earlier, the validity of the power rig as a reference tool is questionable, given the methodological weaknesses in the study. Also, the leg extensor power rig only measures single leg extension power, whereas the Keiser pneumatic leg press measures bilateral leg extension power. Hence, there is reason to question the validity of this instrument.

The goal of this review was to identify instruments that could be used to measure multijoint leg extension power that could be used to prescribe exercise. To do this, they must provide an accurate representation of a person's maximum leg extension power, compared with the reference standard. The studies included in this review used correlational analysis to assess validity, which does not

Table 2 Assessment of included studies on specific criterions for critically appraising the available instruments

| Criterion | Bassey and Short[28] | Yamauchi and Ishii[29] | Thomas et al[30] |
|---|---|---|---|
| Measures maximum multijoint leg extension power | No | Yes | Yes |
| Criterion standard for comparison validity documented? | Yes | No | No<br>Comments: The authors used the leg extensor power rig. |
| Methods were reproducible | No | Yes | Yes |
| Did the power measured by this tool accurately represent the max power obtained from the criterion standard? | Unclear | Unclear | Unclear |
| | Comments: All 3 studies used correlation analysis, but they do not describe how close the absolute power measures from the 2 measurement methods were. | | |
| Commercially available | Unclear | No | Yes |
| Presence of conflict of interest | Undeclared | Undeclared | Undeclared |
| Financial support | Yes | Undeclared | Undeclared |

describe how close the absolute power from the 2 devices is.[34] For instance, the power measured by 2 tools may be significantly correlated even when 1 instrument gives measured power values that are double that of the reference instrument. In this case, the measure of power would not be appropriate for exercise prescription. Bland-Altman analysis would have been an appropriate approach to assess this aspect of validity.[27] This test gives an estimate of the agreement between 2 measurement tools and explains whether 1 method is equal to, and can replace, the other. Unfortunately, none of the studies in this review included this analysis.

### Study limitations

This review did not include studies, such as randomized controlled trials, for which standardized tools for guiding the critical appraisal of study quality exist. Therefore, we developed critical appraisal criteria based on the principles of experimental design (see table 2).

## Conclusions

We were unable to identify a tool to measure maximum multijoint leg extension power that met the review inclusion criteria.

### Future directions

Future research should focus on developing a tool that accurately measures multijoint lower extremity extension power that is safe for use in older and frail individuals. Such a tool could be used to prescribe power exercise and assess the effects of rehabilitation interventions in this population.

## Suppliers

a. Leg extensor power rig; University of Nottingham Medical School.
b. Servo-controlled dynamometer; Matsushita Electric Works.
c. Keiser pneumatic leg press machine; Keiser Sports Health Equipment Inc.
d. Jump gauge; Takei Scientific Instruments Co Ltd.

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