# VALIDITY AND RELIABILITY OF SUBMAXIMAL FITNESS TESTS BASED ON PERCEPTUAL VARIABLES

Matteo Crotti[1], Andrea Bosio[2], Pietro L. Invernizzi[3]

[1]School of Exercise and Sports Sciences, Università degli Studi di Milano, Milan, Italy

[2]Human Performance Laboratory, Mapeisport Research Centre, Varese, Italy

[3]Department of Biomedical Sciences for Health, Università degli studi di Milano, Italy

**Corresponding author:**

Prof. Pietro Luigi Invernizzi

Department of Biomedical Sciences for Health

Università degli Studi di Milano, Milan, Italy

Address: Via Kramer 4/A, 20129, Milan, Italy

Email: pietro.invernizzi1@unimi.it

Phone: +39 02 503 15163

Fax: +39 02 503 15163

**Other authors:**

Matteo Crotti; Email: crotti.mc@gmail.com; Phone: +39 3202318944

Andrea Bosio; Email: and.bos@tiscali.it; Phone: +39 3392731823

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## ABSTRACT

BACKGROUND: Few studies examined the validity of fitness tests based on perception scales. The field-based fitness tests batteries are composed by maximal tests and currently, a battery of submaximal tests does not exist.

METHODS: Seventeen physically active male participants (age 40,5 ± 10,7 years) performed the Multistage fitness test, the Crunch test, the Push-up test and a Trunk flexion test with a submaximal protocol based on perceptual variables that were defined as non-validated submaximal. The mentioned tests were repeated three times to assess their reliability. The participants also performed four validated maximal tests comprising a velocity dependent ramp test on the treadmill, the Crunch test, the Push-up test, and Sit-and-reach test. The submaximal tests were correlated to the maximal ones to assess their criterion validity.

RESULTS: All the submaximal tests showed an ICC superior to 0.8 apart from the submaximal Crunch test. The correlation between maximal treadmill test and submaximal Multistage fitness test was 0.77. The correlation between Sit-and-reach test and submaximal Trunk flexion test was 0.71. Correlations equal to 0.66 and 0.60 were found between the maximal and submaximal Crunch test and push-up test respectively.

CONCLUSIONS: The use of submaximal tests based on a fixed value of perception can represent a suitable tool to assess cardiorespiratory fitness and flexibility because of their correlation with the corresponding maximal evaluation tests and because of their reliability. On the contrary, muscular endurance capacity seems not to be assessable in the same manner.


**Keywords:** Perception, Physical Fitness, Exercise Test, Reliability

## INTRODUCTION

It is well documented by scientific literature that fit people present lower mortality and morbidity rates together with better physical and physiological health status compared to unfit people [1-6]. Given the importance of fitness level for health it is fundamental to create tools that allow to monitor it and its different components comprising endurance, strength and flexibility. The most accurate and reliable methods to evaluate physical fitness require sophisticated instruments such as spirometers, metabolimeter, accelerometers, ergometers, dinamometers and force platforms [2]. Unfortunately, most of the mentioned tools present some characteristics that might limit their use in field-based research and in testing a great number of participants. In fact, most of them are expensive and, as a consequence, it might be difficult for several public or private organizations to afford their costs. Furthermore, as this tools are used in specialized scientific laboratories, it could be difficult to move them from a place to another. Lastly, they do not allow to evaluate several participants simultaneously or in a short amount of time. As an alternative to laboratory testing, several field-based batteries of tests have been validated such as the Health-Related Fitness Test Battery for Adults, the AAHPERD, the Fitness Canada and the Eurofit for adults [7-11]. These type of tests batteries allow to assess a great amount of participants in a relatively short amount of time without the need of expensive equipment moreover, they are suitable to evaluate the different components of the physical fitness. Currently, all the field-based fitness tests batteries are composed by maximal tests which are commonly considered safe for people's health [12-14]. However, the safety of maximal tests could be argued as previous studies analyzing it involved highly qualified experts in a controlled environment where the health story, and the possible risks for the participant's health were well known differently from what might happen in real life settings [12-14]. Otherwise, submaximal testing could be considered as the most appropriate way to monitor physical fitness when some variables concerning participants health are not known, or when the participants do not tolerate strenuous efforts or when the tests are not administered by experts [15]. It should be noted that a field-based alternative to maximal tests, such as a battery of submaximal tests, does not exist. During everyday-sessions of sport and physical activity, where little equipment is available and only few information are available about people's health risks, the employment of submaximal tests based on hearth rate, blood pressure, rate of perceived exertion and other types of perceptual variables could provide valid and helpful information regarding people's capacity to tolerate physical activity [15]. A growing interest in quantifying perceptual variables such as exertion, pain, comfort or temperature led to the validation of several perception scales. However, the studies examining the validity of fitness tests based on perception only regard the evaluation of cardiorespiratory fitness [2, 16]. Indeed, it is possible to evaluate cardiorespiratory fitness using submaximal testing thanks to the relation between rate of perceived exertion and workload [16-18]. On the contrary, submaximal tests to evaluate strength and flexibility do not exist even if perception scales of strength performance and stretching intensity have been validated. On the basis of what previously said, this study aims to validate a battery of submaximal field-based fitness tests that takes in consideration perceptual variables such as rate of perceived exertion and stretching intensity to evaluate endurance, strength and flexibility in adults [19-22]. It is hypothesized that the submaximal tests represent a valid and reliable tool to assess an individual's physical fitness without the exertion of maximal strain.



## METHODS

### Participants

Seventeen male participants practicing running regularly at competitive or non-competitive level were recruited in this study (Table I). The participants were instructed to follow their normal training activities and to refrain from participating in competition or strenuous maximal tests during the period of participation to the study. Moreover, they were required not to drink alcohol *or* caffeine during the testing days.  All the participants signed an informed consent after a detailed explanation of the procedures and possible risks and after being informed that they could interrupt the participation to the study at any time. The study protocol was approved by the Ethics Committee of our Institution and was in accordance with the Declaration of Helsinki for the Humans Rights.

**Fitness testing**

*Maximal cardiorespiratory fitness test*

The maximum oxygen uptake (VO2max) was assessed using a velocity dependent ramp test protocol performed on a treadmill as it has been demonstrated that this type of protocol is appropriate for cardiorespiratory testing [23]. A commercially available metabolimeter (Fitmate PRO, Cosmed, Roma, Italy), calibrated prior to each test according to the manual, was used to monitor continuously the oxygen uptake during the test. The protocol of the test involved 5 minutes at a velocity of 8 km/h followed by an increase in speed of 1 km/h every minute [24]. The test terminated when a person could no longer maintain the speed.

*Maximal Muscular endurance*

The Crunch test and the Push-up test described below were used to assess the muscular endurance of Rectus abdominis and upper limbs muscles respectively as they are considered valid, reliable tests to assess this construct [22, 25, 26]. The participants were asked to lie in a supine position and had to flex their trunk, reaching their hands forward. A metronome was set at 40 beats per minute At the first beep, the subject began the curl-up, reaching the top position at the second beep and returning to the starting position at the third. Repetitions were counted each time the subject reached the bottom position. The test was concluded either when the subject reached 75 curl-ups, or the cadence was broken.

The Push-up test started with the participant in a standard down position with hands pointing forward and under the shoulder, back straight, head up, and using the toes as the pivotal point.

During the test, the participants had to raise the body by straightening the arms and to return to the down position after that, until their chin touched the floor The maximal number of push-ups performed consecutively without rest was counted as the score.

*Maximal Flexibility*

The Sit-and-reach test was used to assess the flexibility as it is considered a valid and reliable test to assess the flexibility of the posterior chain muscles [27, 28]. This test consists in a trunk flexion from a seated position. The distance in centimeters between the top of the middle fingers and the axis passing between the extremities of the heels was recorded.

*Submaximal cardiorespiratory fitness test*

The Multistage fitness test, also called shuttle run test, is represented by a shuttle running between two markers placed 20 meters apart at a progressively increasing speed. This test is widely used to evaluate the cardiorespiratory fitness as it was demonstrated to be a valid tool to predict VO2max [29]. Moreover, the Multistage fitness test was used in previous studies to predict VO2max form submaximal performances by means of the existent relation between workload and perceived exertion [16, 30, 31]. The participants were asked to perform the Multistage fitness test and to interrupt the performance when they perceived an exertion equal to 5 (strong) on the CR-10 Borg's Scale. The distance covered during the whole test was recorded. Previous studies suggested not to exceed an RPE equal to 15 (hard) on the 6-20 Borg's Scale to reduce the risk of cardiovascular disease in clinical populations [30]. As an RPE equal to 5 on the CR-10 Borg's Scale corresponds to an RPE of 15 on the 6-20 Borg's Scale we decided to use it as an endpoint for the submaximal testing [32, 33]. The same criterion was applied to the submaximal Crunch test and to the Submaximal Push-up test presented in this study. We decided to use the CR-10 Borg's Scale instead of 6-20 Borg's Scale because it is suitable for the assessment of the RPE both during endurance and during resistance exercise [34, 35].

*Submaximal muscular endurance tests*

The same protocol of the Crunch test was used for the submaximal testing of the abdominal muscular endurance defined submaximal Crunch test, however, the participants were required to stop the test when they perceived an exertion equal to 5 (strong) on the CR-10 Borg's Scale [33]. The muscular endurance of the upper limbs was tested using a modified version of the Push-up test defined submaximal Push-up test where the participants were asked to execute the push-ups at a pace of 40 beats per minutes and to interrupt the performance when they perceived an exertion equal to 5 (strong) on the CR-10 Borg's Scale.

*Submaximal flexibility tests*

An exercise of trunk flexion from a standing position defined submaximal Trunk flexion test was used to assess the flexibility of the posterior chain in a submaximal way. The participants were asked to stand on a 40 cm high stair and to perform a trunk flexion maintaining the leg in a straight position. In particular, the participants were instructed to reach the highest level of trunk flexion without feeling pain, according to the stretching intensity scale (SIS) [36], and the distance between the extremity of the fingers and the plane of the stair where the participants were standing was assessed.



**Protocol**

The participants took part in one testing session per week for five consecutive weeks at the same time and during the same day of the week. During the first day, the participants did a familiarization to the tests' protocols and to the perceptual scales. During the other four days, the participants performed all the maximal tests or all the submaximal tests selected in this study in a specific order (Figure 1).

****Figure 1 about here****

Three testing days concerned submaximal tests while only one testing day concerned maximal tests, therefore, the participants performed the submaximal tests three times and the maximal tests one time. The order of the testing days was randomized (Figure 2).

****Figure 2 about here****

All the submaximal tests selected for the validation in this study were chosen because they satisfy the assumption of logic validity. Indeed, all the submaximal tests of endurance and muscular endurance used in this study present the protocol of previously validated tests such as the Multistage fitness test, the Crunch test and the Push-up test [18, 22, 25, 26, 29, 37, 38]. Differently, the logic validity of the submaximal test of flexibility is guaranteed by the fact that it involves the same movements assessed by the validated test used as a standard in this study and in other studies such as trunk flexion and hip flexion [22, 39, 40].



**Statistical analysis**

The statistical analysis was performed using the software "SPSS statistics 20". The relative reliability of the submaximal tests, that consists in the degree to which individuals maintain their position in a sample with repeated measurement, was assessed calculating the Intraclass Correlation Coefficient (ICC) [41]. The absolute reliability of the submaximal tests, that consists in the degree to which repeated measurements vary from individuals, was evaluated by means of the standard error of the measurement (SEM) [41]. The Shapiro-Wilk test was used to assess the normality assumption of the data distribution. The Pearson and Spearman tests were used to evaluate the correlation between submaximal tests and maximal tests evaluating the same construct in order to assess the construct validity of the submaximal tests. The Pearson correlation was used when the data distribution satisfied the assumption of normality, on the contrary, when the assumption was violated the Spearman correlation was employed. An ICC equal or superior to 0.8 was the criterion to accept the reliability of the tests while a correlation equal or superior to 0.7 was the criterion to accept the construct validity of the submaximal tests [41].

## RESULTS

Most of the data resulted normally distributed apart from the results of the submaximal Push-up test and the maximal Crunch test. The results of the maximal and submaximal tests are presented in Table II and Table III.

**** Table II, Table III about here****

The ICC analysis showed significant results (all p-values lower than 0.05) with all the submaximal tests showing an ICC superior to 0.8 apart from the submaximal Crunch test (Table IV).

**** Table IV about here****

The SEM values were heterogeneous as the submaximal tests presented in this study concerned different fitness variables and involved different unit of measurement apart from the submaximal Crunch test and the submaximal Push-up test which both comprised arbitrary units (a.u.). In particular, the multistage fitness test showed a SEM of 102 m, the submaximal Crunch test showed a SEM of 4.08 a.u., the submaximal Push-up showed a SEM of 2.02 a.u. and the Submaximal trunk flexion test showed a SEM of 1.85 cm. Interestingly, the SEM of the submaximal Crunch test was more than twice the SEM of the submaximal Push-up test.

**** Table V about here****

A relation between the submaximal and the maximal tests evaluating the same construct was found in all of the test with moderate to low correlations (Figure 3). The correlation between maximal treadmill test and submaximal Multistage fitness test was the highest found in this study with a correlation coefficient equal to 0.77. Similarly, a significant correlation was found between Sit-and-reach test and submaximal Trunk flexion with a coefficient equal to 0.71. Significant moderate correlations were found between maximal and submaximal test of muscular endurance performance, indeed correlations equal to 0.66 and 0.60 were found between the maximal and submaximal Crunch test and push-up test respectively (Figure 3).



****Figure 3 about here****

## DISCUSSION

The submaximal Multistage fitness test and Trunk flexion test are the only two tests that satisfied the assumption of criterion validity obtaining a correlation with their reference standard higher than 0.7. The submaximal Multistage fitness test is the one that showed the highest correlation (r = 0.77) with the respective reference standard represented by the VO2max measured during an incremental running test to exhaustion performed on a treadmill. This is in line with previous studies where the submaximal rate of perceived exertion was used to estimate the VO2max [30, 31]. A relation was found between maximal Crunch test and submaximal Crunch tests (ρ = 0.60). A similar relation was found between submaximal and maximal Push-up tests with a correlation coefficient equal to 0.66. Unfortunately, these relations does not satisfy the standards for the assumption of criterion validity [41]. The difference between the protocol of the maximal tests and the protocol of the submaximal tests could be the cause of the low correlations. Indeed, previous studies showed a low correlation (< 0.50) between fitness tests designed to assess abdominal muscular endurance which presented slightly different protocols [42]. A further explanation to the low correlations could be attributed to the people's neuromuscular characteristics. In particular, the participants with a higher percentage of type I fibers could be able to execute a relatively higher number of repetitions after reaching a perceived exertion equal to 5 on the Borg's scale compared to the other participants [43]. In addition, a recent study of Grosicki et al. reported a high between-subject variability in muscular endurance performances [44]. In the mentioned study the participants performed a bicep curl exercise at 60% of their Maximal Voluntary Contraction (MVC) until exhaustion and, as a result, a great between-subject variability in the number of repetition was reported [44]. Knowing that people report equal RPE scores at the same MCV% it is possible to say that there is a substantial variability in the number of repetitions that people can perform during a muscular endurance exercise after the onset of the fatigue [34, 45]. As regards the flexibility tests, a correlation equal to 0.71 was found between the submaximal Trunk flexion test and the Sit-and-reach test. Notably, this correlation is higher than the ones recorded in previous studies where the Sit-and-reach test was used as a reference standard for criterion validity to validate the back saver Sit-and-reach test and correlations between 0.45 and 0.65 were found [39]. Therefore, the submaximal Trunk flexion test is a better estimator of posterior chain muscles flexibility than other previously published test such as the sit and reach back saver test [39].

Three of the submaximal tests satisfied the reliability criteria by achieving an ICC superior to 0.80 while only the submaximal Crunch test did not satisfy this criterion. Particularly, the submaximal Multistage fitness test and Trunk flexion test presented the highest values of reliability with an ICC equal to 0.94 and 0.96 respectively. These results are in line with the reliability coefficients found in previous studies concerning the Multistage fitness test and the Sit-and-reach test where ICCs between 0,92 and 0,96 were found for the first test and 0,94 for the second [7, 30]. The submaximal Push-up test also presented reliable results showing an ICC equal to 0.85. Notably, the submaximal Push-up test showed a higher reliability than the Push-up test performed in previous studies (ICC = 0.73) [46]. Only the submaximal Crunch test presented a low reliability with an ICC equal to 0.76. This results is slightly lower than the one obtained by adults performing the sit-up test of the Eurofit battery of adults (ICC = 0.83), that evaluates muscular endurance of the Rectus abdominis muscles [7]. However, it should be noted that the Crunch test and the sit-up test present different protocols [7]. The SEM was also evaluated in this study (Table V) as it is considered a parameter of absolute reliability that consists in the degree to which repeated measures vary for individuals [41]. The SEM is necessary to evaluate the capacity of a test to monitor the changes over time. In other words, SEM allows to assess to which extent a test provides accurate scores. Furthermore, it could represent a practical indication for the people who use the tests to understand whether the change in the measurement over time is due to measurement errors or to other factors such as the effect of a training. Unfortunately, the lack of data in the current literature concerning the SEM in fitness test similar to the ones exposed in this study make it difficult to interpret this results. However, a method to interpret the SEM was proposed by clinimetrics, that is a methodological discipline which investigates the quality of medical research and clinical practice [47]. Clinimetrics established that the amount of absolute error of the measurement (e.g. SEM) should be lower than the minimal amount of change that is considered to be relevant, also called Minimal Important Change (MIC) [48]. Hopkins was the first who proposed to apply this concept to the field of sport performance, and he suggested that the MIC related to performance variables and the absolute error of the measurement of exercise tests should be calculated to assess whether a test is appropriate or not for a specific purpose [49]. Impellizzeri and colleagues applied this method in a study concerning the evaluation of the validity of a repeated sprint ability test in soccer players [50].

The main limit of this study is the fact that the participants are not representative of the general population as the sample was composed by people who regularly participate in physical activity and therefore presents a good or high fitness level. In fact, a great part of the population is represented by people who are unfit, obese or overweight and sedentary. It is possible that people with low level of fitness and experience in physical activity might have difficulties in performing submaximal tests based on their perception given their lack of practice in the evaluation of their self-perception during physical efforts. Therefore, It is fundamental to make people familiarize and practice with perceptual scales, such as the Borg scale and the SIS scale, according to the indication presented by the respective authors of the scales [33, 36].

## CONCLUSIONS

The submaximal Multistage fitness test and the submaximal Trunk flexion test satisfied the standard for logic validity, criterion validity and reliability and therefore can be considered as valid tools to assess cardiorespiratory fitness and flexibility respectively. The submaximal Crunch test did not show an adequate reliability and correlation with the maximal Crunch test while the submaximal Push-up test did not satisfy the standard of criterion validity, therefore, both the tests cannot be considered a valid tool to predict maximal muscular endurance capacities. Consequently, submaximal tests based on perception seem to be a suitable method to evaluate cardiorespiratory fitness and flexibility while they seem to be inadequate to assess muscular endurance capacities. On the basis of the finding of this study future research in the field of fitness and wellness should consider the opportunity to implement and validate submaximal fitness test based on perception to evaluate cardiorespiratory fitness and flexibility. Future studies should clarify the relation between rate of perceived exertion (internal load), load (%MVC) and number of repetitions, and the factors that might influence this relation should be identified. The practitioners that work in the field of health promotion could consider new ways of training and testing based on the perceptions or internal load rather than on external load. This could help to avoid problems like injuries and overtraining and it could educate the people to new perspectives of self-awareness and knowledge. This might help fostering health and wellness in the population.

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**Table I. - Demographic information of the subjects.**

| Participants | Mean | Std. Deviation |
|---|---|---|
| Age (yrs) | 40.5 | 10.7 |
| Body mass (Kg) | 69.3 | 4.7 |
| Staure (cm) | 174.6 | 6.2 |
| Body Mass Index | 22.7 | 1.1 |

**Table II. – Descriptive statistics of the submaximal tests.**

| Submaximal test | Minimum | Maximum | Mean | Std. Deviation | Units |
|---|---|---|---|---|---|
| Submaximal Multistage fitness test | 1133 | 2527 | 1656.9 | 413.6 | m |
| Submaximal Crunch test | 10.3 | 40 | 23.4 | 8.7 | a.u. |
| Submaximal Push-up test | 6 | 22 | 12.3 | 4.6 | a.u. |
| Submaximal Trunk flexion test | -5 | 20 | 8.9 | 8.0 | cm |

a.u. = arbitrary units

**Table III. - Descriptive statistics of the maximal tests.**

| Maximal tests | Minimum | Maximum | Mean | Std. Deviation | Units |
|---|---|---|---|---|---|
| Treadmill test | 45.6 | 65.2 | 55.5 | 5.8 | ml · kg-1 · min-1 |
| Crunch test | 15 | 75 | 35.7 | 18.1 | a.u. |
| Push-up test | 12 | 42 | 21.3 | 7.7 | a.u. |
| Sit-and-reach | 7 | 48 | 29.9 | 10.5 | cm |

a.u. = arbitrary units

**Table IV. – Relative reliability of the submaximal tests.**

| | | 95% Confidence Interval | | |
|---|---|---|---|---|
| **Submaximal test** | ICC | Lower Bound | Upper Bound | p-value |
| Submaximal Multistage fitness test | 0.953 | 0.905 | 0.979 | $p < 0.001$ |
| Submaximal Crunch test | 0.756 | 0.570 | 0.883 | $p < 0.001$ |
| Submaximal Push-up test | 0.853 | 0.725 | 0.932 | $p < 0.001$ |
| Submaximal Trunk flexion test | 0.946 | 0.892 | 0.976 | $p < 0.001$ |

ICC: Intraclass Correlation.

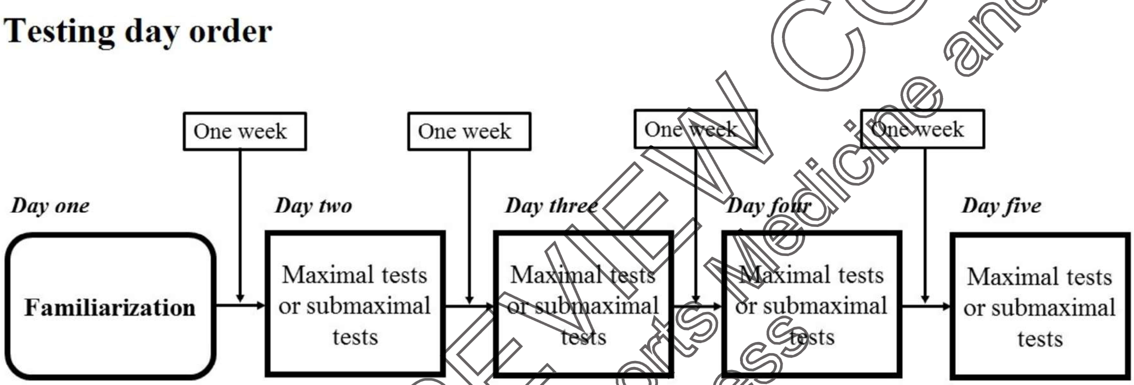
**Table V. – Absolute reliability of the submaximal tests.**

| **Submaximal test** | SEM | Units |
|---|---|---|
| Multistage fitness test | 102 | m |
| Submax Crunch test | 4.08 | a.u. |
| Submax Push-up test | 2.02 | a.u. |
| Submaximal Trunk flexion test | 1.85 | cm |

a.u. : arbitrary units; SEM: Standard Error of the Measurement.

**Test order**

| **Maximal tests day** | **Submaximal tests day** |
|---|---|
| Tests order: | Tests order: |
| 1. Sit-and-reach test | 1. Submaximal Trunk flexion test |
| 2. Crunch test | 2. Submaximal Crunch test |
| 3. Push-up test | 3. Submaximal Push-up test |
| 4. Treadmill test | 4. Submaximal Multistage fitness test |


Testing day order
One week
One week
One week
One week
Day one
Day two
Day three
Day four
Day five
Familiarization
Maximal tests or submaximal tests
Maximal tests or submaximal tests
Maximal tests or submaximal tests
Maximal tests or submaximal tests

**Correlation between maximal and submaximal tests**