EUFITMOS fitness testing protocol

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EUROPEAN FITNESS MONITORING SYSTEM
(EUFITMOS) ERASMUS+ SPORT PROJECT

EUFITMOS fitness testing protocol

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Introduction

Physical activity is defined as a body movement produced by the contraction of skeletal muscles that increase energy expenditure. Increased physical activity results in higher physical fitness, which is understood as an indicator of health, specifically, the ability to perform and maintain daily tasks with moderate or vigorous intensity, efficiently and with sufficient energy without undue fatigue.

The purpose of physical fitness is twofold: health-related and performance-related. Health-related physical fitness components include body composition measures (i.e., body mass index, waist circumference), cardiorespiratory fitness, muscular fitness, speed, agility, balance, and coordination. These components have been consistently associated with indicators of obesity, cardiovascular health, metabolic health, bone health, and mental health. Therefore, the increase and maintenance of physical fitness are associated with health benefits, not only in terms of physical well-being but also emotional, social, or even cognitive. For these reasons, the monitoring of physical fitness is important because it reflects the impact of genetic and environmental factors on health indicators.

Based on the physical fitness level of children, pedagogical, and public health strategies and policies can be developed. In this sense, it is necessary to have a battery of validated fitness tests, capable of assessing physical fitness to obtain data that allow us to determine the level of health and at the same time establish comparisons between European countries.

The European Fitness Monitoring System (EUFITMOS) project (funded by the Erasmus+ program) aims to develop a European monitoring system for adolescents' physical fitness. We dedicate our attention to school-age adolescents because a healthy childhood and adolescence have a long-lasting effect on health in adulthood. Thus, we decided to develop a standardized test battery, which is applicable throughout schools in Europe and capable of assessing physical fitness in all health-related facets. In this context, reliable assessment tools are essential to get valid and accurate results. In particular, the feasibility is important to assure high compliance and commitment in most European schools. Initially, we conducted a systematic review, including a review of previous reviews, to identify the existing test batteries[1]. Then, scholars from six European countries (Germany, Greece, Montenegro, Portugal, Slovenia, and Spain) helped to choose the tests that are, in their opinion, applicable in the school systems

[1] Marques, A., Henriques-Neto, D., Peralta, M., Martins, J., Gomes, F., Popovic, S., Masanovic, B., Demtriou, Y., Schulund, A., & *Ihle, A. (2021). Field-based health-related physical fitness tests in children and adolescents: a systematic review. Frontiers in Public Health, 9, 640028. https://doi.org/10.3389/fped.2021.640028*

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throughout Europe. Finally, the experts consent to the physical fitness test battery for the EUFITMOS project, which is presented in this manual.
We intend to apply and disseminate the test battery all over Europe. We further want to encourage researchers to assess the level of physical fitness in adolescents by using this manual because the derived findings will inform the development of pedagogical public health strategies and European physical fitness recommendations.

The battery of tests presented are the following:

Test	Purpose
PACER	The Progressive Aerobic Cardiovascular Endurance Run (PACER), or multistage 20m shuttle run, is an established endurance test that aims to measure cardiorespiratory fitness.
1-mile run	The 1-mile run aims to assess aerobic capacity.
Push-up test	The push-up test aims to assess upper-body strength and resistance.
Handgrip	The handgrip test aims to measure maximum isometric strength.
Standing broad jump	The standing broad jump, or standing long jump, aims to assess lower-body muscular power and explosive strength.
20m run	The 20m run aims to assess acceleration and speed.
Back-saver sit and reach	The back-saver sit and reach test aims to evaluate the flexibility of the lower back and the hamstrings.
Body mass index	The body mass index (BMI) is an established assessment of body composition.
Waist circumference	Waist circumference (WC) aims to estimate abdominal adiposity.

Each one of these tests are presented with the objective of facilitating its use by the teachers. That is done through the description of the following fields: name of the test, purpose, equipment required, procedure, scoring, validity and/or reliability. After the description of each test, it is also presented some images to facilitate the visual understanding of the future battery user.

PACER

Purpose

The Progressive Aerobic Cardiovascular Endurance Run (PACER), or multistage 20m shuttle run, is an established endurance test that aims to measure cardiorespiratory fitness.

Equipment required

An open space of 20m for running (plus at least 2m on each side), marker cones or tape, measuring tape, the PACER score sheet, and PACER soundtrack are needed. Tape and cones should mark two parallel lines 20m apart.

Procedure

The PACER uses a time cadence. It starts at a pace of 8.5 km/h and increases by 0.5 km/h per minute.
At the "start" signal the participant runs from the starting line to the opposite line. The participant must reach the line before a "beep" sound signal is audible. Whenever the participant hears the sound signal, he/she must start running to the opposite line. This is repeated until the participant is unable to continue, commits two fouls (e.g., unable to reach a line, running before the sound signal, remaining in the same line for two consecutive sound signals), or finishes the PACER soundtrack. A "triple beep" sound signal is audible at each minute, marking the increase in cadence and pacing.
Beforehand, the test itself (and scoring procedures) should be explained. It is recommended that participants are given pacing instructions; a reduced trial session (e.g. including the first 6 laps of PACER) may be warranted.

Scoring

Usually, this test is performed in groups, enabling several participants to be tested at once. If the participants are capable of scoring, they score each other in pairs.
The scorer stands where the runner's touching of the lines is visible and crosses a number on the PACER sheet every time the runner completes a lap. If the runner fails to reach the line before the sound signal, a circle is placed around the lap number, marking it as a foul. If two fouls are marked, the test ends.
The last crossed lap is considered the final score. The recorded number of laps is then converted to VO2max (Saint-Maurice et al., 2015) and compared to the sex and age-specific health-related reference values (see Apendix 1).

Validity and/or reliability

The PACER shows moderate criterion validity and high to very high reliability (Tomkinson et al., 2019).

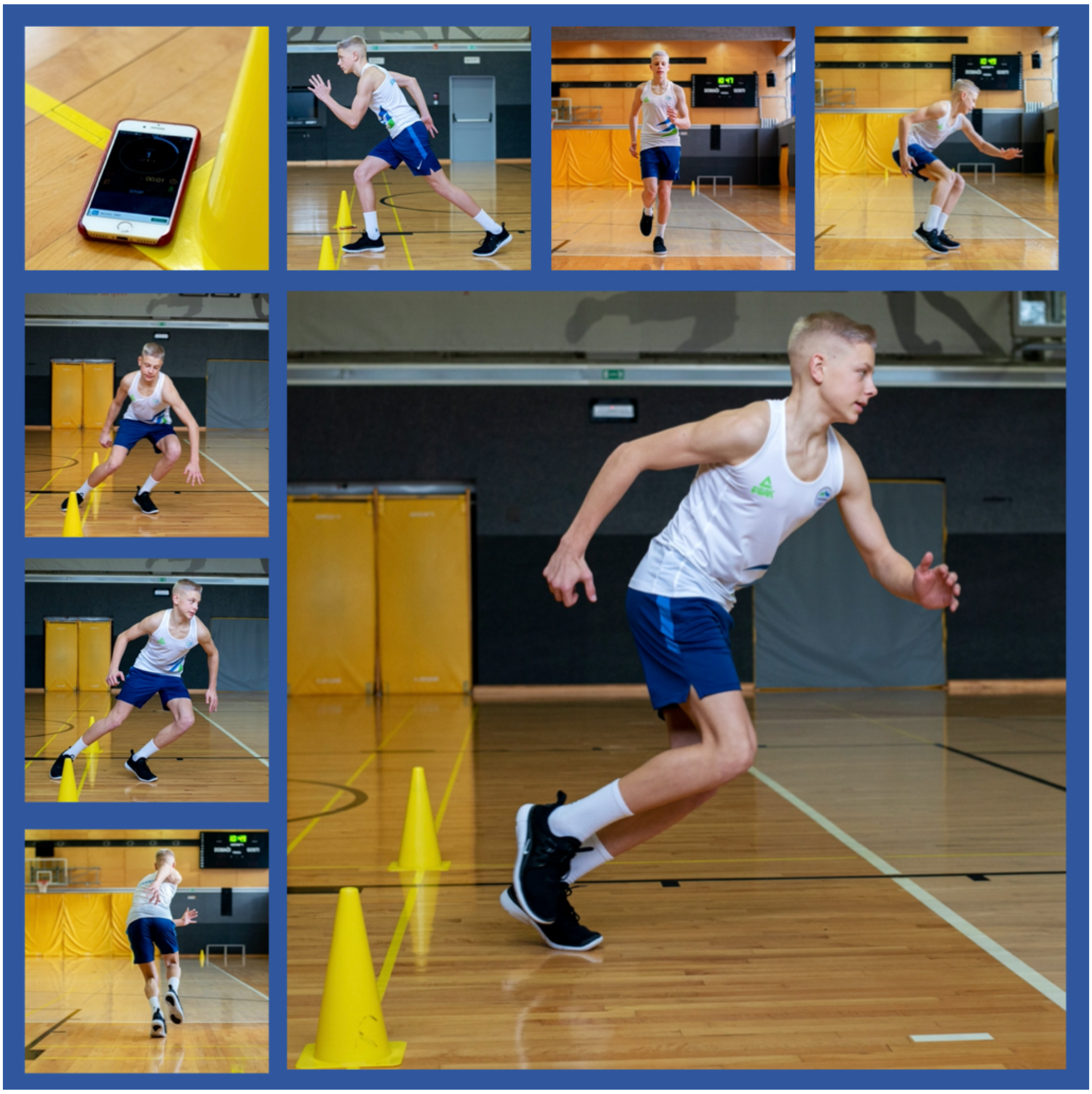

Figure 1. Progressive Aerobic Cardiovascular Endurance Run (PACER).

1-mile run

Purpose

The 1-mile run aims to assess aerobic capacity.

Equipment required

1-mile (~1609m) flat running course/area (e.g. 4x400m track plus 9m, flat open space, gymnasium), marker cones, scoring sheet, a stopwatch, measuring tape or cross-country wheel (in case the running course area needs to be measured) are needed.

Procedure

The goal is to complete a 1-mile course as fast as possible at a steady running pace. Walking at a fast pace is allowed. Participants run the length of the course and their finishing time is recorded. The starting and finish line should be marked with visible objects.
Before beginning the test, the participant stands behind the starting line and at the "go" signal the participant starts running and the stopwatch begins timing. Participants should keep a steady cadence throughout the course. The test ends when the participant crosses the finish line, covering the 1-mile distance. After that, the participant should go for a "return-to-calm" walk.
Beforehand, the test itself (and scoring procedures) should be explained. It is recommended that participants receive pacing instructions.

Scoring

Scoring includes tracking distance or number of laps (if a pre-determined number of laps is established) and counting time using a stopwatch. At the moment the participant crosses the finish line, the scorer stops the stopwatch, registering the minutes and seconds taken to perform the test. Scorers should stand in a place where the runner is always visible to them.
Usually, this test is performed in groups, enabling several participants to be tested at once. The recorded time is then compared to the sex and age-specific health-related reference values (see Apendix 1).

Validity and/or reliability

The 1-mile run test shows moderate validity to estimate VO2peak (Cureton et al., 1995) and moderate-to-high reliability (Beets & Pitetti, 2006).

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Figure 2. 1-mile run.

Push-up test

Purpose

The push-up test aims to assess upper-body strength and resistance.

Equipment required

Floor mat and audio with test cadence or metronome (or similar) pacing 20 push-ups per minute are needed.

Procedure

The participant starts in the plank position, hands and toes touching the floor, elbows in extension, feet slightly apart, hands facing forward in line with the shoulders.

At the "down" sound signal, keeping torso and legs in a straight line, the participant bends the elbows until arm and forearm form an 90º angle. At the "up" sound signal the participant returns to the plank position until the elbow is fully extend. This is repeated until the participant commits two fouls, is unable to continue, or the test ends. The cadence marks 20 complete pushups each minute; it takes 3 seconds to perform a complete pushup.

It is a foul when the participant does not respect the sound signal instructions, does not reach the 90º angle between arm and forearm, does not fully extend the elbows when returning to the plank position, or is not able to keep the body in a straight line. After the participant commits two fouls, the test ends. Beforehand, the test itself (and scoring procedures) should be explained.

Scoring

The score is the number of completed push-ups, which should be noted by a scorer. Usually, this test is performed in groups, enabling several participants to be tested at once. If the participants are capable of scoring, they can be paired up and score each other.

The number of completed push-ups is compared to the sex and age-specific health-related reference values (see Apendix 2).

Validity and/or reliability

The pushup test has sufficient evidence to relate its score with the strength and endurance of the upper arm and shoulder girdle (Baumgartner et al., 2002). It should be noted that the performance of overweight children and adolescents might be weaker (Castro-Piñero et al., 2010).

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Figure 3. Push-up test.

Handgrip

Purpose

The handgrip test aims to measure maximum isometric strength.

Equipment required

Hand dynamometer.

Procedure

The procedure protocol for the handgrip test varies according to the dynamometer brand used. Therefore, the procedures presented in this protocol are as generic as possible.

The dynamometer should first be checked in order to assess that it is functioning properly. The needle is to be set at the 0kg mark, and adjusted to the participant's hand size, so that the participant feels comfortable (the squeezing handle is placed between the middle and the proximal phalanges).

The participant is positioned as such: standing position, feet shoulder-width apart, holding the dynamometer with the elbow in full extension, with the arm still and at the side of, and slightly away from the body.

The participant squeezes as tightly as possible for at least two seconds. This procedure is performed two times in each hand with a 1-minute rest between trials. Verbal encouragement is recommended to obtain the best result. Beforehand, the test itself (and scoring procedures) should be explained.

Scoring

The best score obtained for each hand is rounded to the nearest 0.1kg and compared to the sex and age-specific health-related reference values (see Apendix 3).

Validity and/or reliability

Grip strength is a valid measure of total muscle strength among children and adolescents (Wind et al., 2010). Even though differences between dynamometer brands exist, the handgrip test offers good reliability (España-Romero et al., 2010).

Figure 4. Handgrip test.

Standing broad jump

Purpose

The standing broad jump, or standing long jump, aims to assess lower-body muscular power and explosive strength.

Equipment required

A non-slippery flat surface/floor, tape, and measuring tape are needed.

Procedure

The participant stands with both feet immediately behind the starting line, with their feet as far apart as their shoulders. Then, the participant slightly bends the knees, swings the arms, and jumps forward, with both feet simultaneously, as far as possible.

The participant must land on both feet and in an upright position. If the participant touches the floor with body parts other than the feet, then the attempt is not valid. The participant can perform two valid attempts, and must be wearing shoes throughout the test.

Beforehand, the test itself (and scoring procedures) should be explained. It is recommended that participants receive jumping instructions. A trial jump is allowed.

Scoring

Using the measuring tape, the jumping distance is assessed in centimeters, perpendicularly to the starting line, from the starting line to the heel of the participant that is closest to the start line. The best result of the two attempts is the final score.

The jumping distance, to the nearest 0.1cm, is compared to the sex and age-specific health-related reference values (see Apendix 4).

Validity and/or reliability

The standing broad jump is considered a valid field-based test to access lower-body muscular power among children (Fernandez-Santos et al., 2015). The standing broad jump presents high reliability from test-retest analysis (Fernandez-Santos et al., 2015).

Figure 5. Standing broad jump.

20m run

Purpose

The 20m run aims to assess acceleration and speed.

Equipment required

A flat and clear floor/surface of at least 30m (including deceleration area), measuring tape or marked track, stopwatch or timing gates, and cone markers are needed.

Procedure

The participant stands still behind the starting line, in a split-stance start position, with one foot in front of the other. On the "go" sound sign, the participant must run as fast as possible to the finish line.

The participant should be encouraged to continue running past the finish line to prevent deceleration before finishing the test. The participant can perform two attempts with a minimum rest time of 3 minutes between attempts.

Beforehand, the test itself (and scoring procedures) should be explained. It is recommended that participants receive running instructions. A trial run is allowed. Additionally, an appropriate warm-up should be provided to the participant.

Scoring

The time in seconds (to the nearest 2 decimal places) is recorded. The best result of the two attempts is the final score. The recorded time is compared to the sex and age-specific health-related reference values (see Apendix 5).

Validity and/or reliability

The 20m run is a reliable test predictor of linear speed (Henriques-Neto et al., 2020; Latorre-Román et al., 2017; Molnar et al., 2009) and both handheld stopwatch and electronic timing gates are reliable assessment devices for the 20m run (Yanci et al., 2017).

Figure 6. 20m run.

Back-saver sit and reach

Purpose

The back-saver sit and reach test aims to evaluate the flexibility of the lower back and the hamstrings.

Equipment required

A box with 30cm height and a ruler (it can be incorporated in the box or attached to it) with the 22.5cm mark on the edge of the box (where participants reach their toes) with the 0cm mark facing the participant.

Procedure

Without shoes, the participant sits on the floor with one leg straight and the other one bent with the foot on the floor. The foot of the straight leg is placed against the measurement box. Then, the participant extends the arms and places one hand on top of the other with the palms facing down and slowly reaches forward as far as possible along the measuring line.

Hands must remain on top of each other. The participant reaches forward and comes back three times and at the fourth reach holds the position, hands on top of each other on the ruler for at least one second. After performing the test with one leg the participant performs the test with the other leg.

Beforehand, the test itself (and scoring procedures) should be explained. It is recommended that participants have a trial session.

Scoring

The score is recorded to the nearest 0.1cm as the distance reached by the tip of the fingers. The best result of the two attempts is the final score. The recorded distance is compared to the sex and age-specific health-related reference values (see Apendix 6).

Validity and/or reliability

The back-saver sit and reach presents a moderate validity for hamstring flexibility, however, it has low validity for lumbar flexibility (Mayorga-Vega et al., 2014). It is a highly reliable test (Patterson et al., 1996).

Figure 7. Back-saver sit and reach.

Body mass index

Purpose

The body mass index (BMI) is an established assessment of body composition.

Equipment required

Scale and height measurement instrument, such as stadiometer or measuring tape are required.

Procedure

To assess weight, the participant should wear minimal light clothing and take their shoes off. The participant steps on the scale and stands straight, without touching surfaces other than the scale, looking forward with the arms relaxed along the body.
To assess height, the participant must take the shoes off and stand straight, facing away from the stadiometer/measuring tape, looking forward with the arms relaxed along the body and both feet together (completely touching the floor/surface) while touching the stadiometer/measuring tape with the shoulder blades and buttocks. The examiner confirms if the participant is in the correct stance and positions the individual's head according to an imaginary line between the center of the ear hole and the lower part of the eye socket ("Frankfort plane"). The participant's height is assessed two times. The participant should step out of the stadiometer/position between each measurement.

Scoring

When the scale value stabilizes, weight is recorded in kilograms to the nearest 0.1kg. Height is recorded in meters to the nearest 0.01m. The mean value of the two height measurements is used. The BMI is obtained by dividing the participant weight (kg) by the square of height (m). The score is compared to the sex and age-specific health-related reference values (see Apendix 9).

Validity and/or reliability

The BMI is moderately sensitive and a specific indicator of excess adiposity among children, although its accuracy varies according to the degree of body fatness (Freedman & Sherry, 2009). It also presents great reliability when measured by professionals, such as physical education teachers (Berkson et al., 2013).

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Figure 8. Height and weight measurement for body mass index (BMI).

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Waist circumference

Purpose

Waist circumference (WC) aims to estimate abdominal adiposity.

Equipment required

A flexible, inelastic measuring tape is required.

Procedure

The WC should be measured in a horizontal plane around the abdomen, at the level of the iliac crest, with the participant standing straight, feet together, and without shoes. The WC is measured directly on the skin. Therefore, the participant should be without a shirt, or may lift the shirt for the assessment.

The examiner should verify if the measuring tape is tight without compressing the skin, and is parallel to the floor. The WC is assessed at the end of a normal expiration. The participant's WC is assessed two times. The examiner should remove the measuring tape from the measurement site between each assessment.

Scoring

The WC is recorded in centimeters to the nearest 0.1cm. The mean value of the two measures is the final score. The WC is compared to the sex and age-specific health-related reference values for the examined population (see Apendix 8).

Validity and/or reliability

The WC is a valid measure of truncal adiposity in children and adolescents (Taylor et al., 2000). Additionally, it is considered a reliable and feasible measure for the general public (Ross et al., 2020).

Figure 9. Waist circumference (WC) measurement.

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Apendices

Apendix 1

Age	VO_{2peak} (ml/kg/min)	
	Healthy fitness zone (≥)	
	Girls	Boys
9	40.2	40.2
10	40.2	40.2
11	40.2	40.2
12	40.1	40.3
13	39.7	41.1
14	39.4	42.5
15	39.1	43.6
16	38.9	44.1
17	38.8	44.2
18+	38.6	44.3

Reference: Welk, G. J., Laurson, K. R., Eisenmann, J. C., & Cureton, K. J. (2011). Development of youth aerobic-capacity standards using receiver operating characteristic curves. *American Journal of Preventive Medicine, 41*(4 Suppl 2), S111-116. https://doi.org/10.1016/j.amepre.2011.07.007

Apendix 2

Age	Push-ups	
	Healthy fitness zone (≥)	
	Girls	Boys
9	6	6
10	7	7
11	7	8
12	7	10
13	7	12
14	7	14
15	7	16
16	7	18
17	7	18
18+	7	18

Reference: Plowman, S. A., & Meredith, M. (2014). *FITNESSGRAM®/ACTIVITYGRAM® Reference Guide (4th ed.)*. The Cooper Institute.

Apendix 3

Age	Handgrip strength (kg)	
	Healthy fitness zone (≥)*	
	Girls	Boys
9	11.6	12.0
10	13.6	13.8
11	16.0	15.8
12	18.2	18.4
13	19.9	21.9
14	21.2	25.7
15	22.1	29.0
16	22.7	31.5
17	23.3	33.2
18+	23.7	34.4

*Note: Values below the reference denote high-risk.

Reference: Saint-Maurice, P. F., Laurson, K., Welk, G. J., Eisenmann, J., Gracia-Marco, L., Artero, E. G., Ortega, F., Ruiz, J. R., Moreno, L. A., Vicente-Rodriguez, G., & Janz, K. F. (2018). Grip strength cutpoints for youth based on a clinically relevant bone health outcome. *Archieves of Osteoporosis, 13*(1), 92. https://doi.org/10.1007/s11657-018-0502-0

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Apendix 4

Standing broad jump (cm)		
Age	Healthy fitness zone (≥)	
	Girls	Boys
9	108.4	102.1
10	110.8	110.2
11	113.3	119.0
12	115.8	128.4
13	118.1	135.4
14	121.8	151.5
15	123.0	165.4
16	126.0	175.9
17	129.5	184.2
18+	131.9	203.2

Reference: Ortega, F. B., Artero, E. G., Ruiz, J. R., Espana-Romero, V., Jimenez-Pavon, D., Vicente-Rodriguez, G., Moreno, L. A., Manios, Y., Beghin, L., Ottevaere, C., Ciarapica, D., Sarri, K., Dietrich, S., Blair, S. N., Kersting, M., Molnar, D., Gonzalez-Gross, M., Gutierrez, A., Sjostrom, M., Castillo, M. J., & study, H. (2011). Physical fitness levels among European adolescents: the HELENA study. British Journal of Sports Medicine, 45(1), 20-29. https://doi.org/10.1136/bjsm.2009.062679

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Apendix 5

Age	20m run (s)	
	Healthy fitness zone (≤)	
	Girls	Boys
9	4.55	4.42
10	4.43	4.28
11	4.32	4.14
12	4.24	4.01
13	4.19	3.89
14	4.16	3.78
15	4.16	3.68
16	4.18	3.58
17	4.23	3.50
18+	4.31	3.42

Reference: Castro-Pinero, J., Gonzalez-Montesinos, J. L., Keating, X. D., Mora, J., Sjostrom, M., & Ruiz, J. R. (2010). Percentile values for running sprint field tests in children ages 6-17 years: influence of weight status. Research Quarterly for Exercise and Sport, 81(2), 143-151. https://doi.org/10.1080/02701367.2010.10599661

Apendix 6

Back-saver sit and reach (cm)		
Age	Healthy fitness zone (≥)	
	Girls	Boys
9	22.9	20.3
10	22.9	20.3
11	25.4	20.3
12	25.4	20.3
13	25.4	20.3
14	25.4	20.3
15	30.5	20.3
16	30.5	20.3
17	30.5	20.3
18+	30.5	20.3

Reference: Plowman, S. A., & Meredith, M. (2014). *FITNESSGRAM®/ACTIVITYGRAM® Reference Guide (4th ed.)*. The Cooper Institute.

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Apendix 7

Body mass index*				
	Healthy fitness zone (≤)			
Age	Girls		Boys	
	>	<	>	<
9	13.3	18.7	13.6	18.2
10	13.7	19.4	13.9	18.8
11	14.1	20.3	14.2	19.5
12	14.7	21.3	14.7	20.4
13	15.2	22.3	15.2	21.3
14	15.7	23.1	15.7	22.2
15	16.0	23.8	16.3	23.1
16	16.3	24.3	16.7	23.9
17	16.4	24.6	17.1	24.6
18+	18.5	25.0	18.5	25.0

*Note: Approximated values for age in years. In the database the World Health Organization reference values are calculated.

Reference: de Onis, M., Onyango, A. W., Borghi, E., Siyam, A., Nishida, C., & Siekmann, J. (2007). Development of a WHO growth reference for school-aged children and adolescents. Bulletin of the World Health Organization, 85(9), 660-667. http://www.ncbi.nlm.nih.gov/pubmed/18026621

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Apendix 8

Age	Waist circumference (cm)*	
	Healthy fitness zone (≤)	
	Girls	Boys
9	66.8	77.1
10	68.9	80.1
11	70.8	82.6
12	72.5	85.1
13	74.2	87.0
14	75.7	88.9
15	76.8	90.5
16	77.7	91.8
17	78.5	92.7
18+	79.2	93.4

*Note: Values from 9 to 11 years old were extrapolated.

Reference: Jolliffe, C. J., & Janssen, I. (2007). Development of age-specific adolescent metabolic syndrome criteria that are linked to the Adult Treatment Panel III and International Diabetes Federation criteria. Journal of the American College of Cardiology, 49(8), 891-898. https://doi.org/10.1016/j.jacc.2006.08.065

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