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UNIQUE FUNCTIONAL PERFORMANCE TESTING FOR THE OVERWEIGHT AND OBESE

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Abstract

Although there are various tests available for the assessment of neuromuscular performance in people with specific needs, functional testing battery for overweight and obese individuals that would be proven in practice is missing. This study provides an effective and functional performance assessment for the overweight and obese. Design of the test battery is based on findings of intervention studies evaluating the effect of 3 months of resistance and aerobic training programs on neuromuscular performance in overweight and obese individuals. It includes tests of endurance (an incremental exercise test on the cycle ergometer), strength and power (maximum voluntary isometric contraction, chair rising and chair jumping, bench press and deadlift to high pull; both with increasing weights), movement speed (visually-triggered step initiation and/or spontaneous step initiation, foot tapping), balance (load release balance test and static balance test under various conditions, visually-guided CoM tracking task). The tests proposed are sensitive in revealing post-training changes, thus would be suitable for implementing in the functional diagnostic for this population, in addition to complementing existing testing methods.

Key words: *neuromuscular functions, obesity, tests, training*

Introduction

Recently, we completed the research project evaluating the effect of different training programs on the neuromuscular performance and metabolism [1] in sedentary middle-aged overweight and obese individuals. Subjects were divided into two groups. While the first group underwent aerobic training, the second one participated in resistance training for a period of 3 months (1 hour sessions, 3-times per week).

Aerobic performance and cardiovascular health status were assessed by cardiologist in the recruitment process, and after completing the 3-month intervention. Maximal aerobic capacity ($\dot{V}O_2max$) was calculated from the continuous measurement of the gas exchange (Ergostik, Geratherm Respiratory, Bad Kissingen, Germany) during an incremental exercise test (Lode-Corival cycle ergometer, Lode B.V., Groningen, the Netherlands) and expressed relative to lean body mass. Each session started with standardized warm-up and finished with cool down stretching exercises. During the training, aerobic dancing, running, and spinning were alternated. During each 1-hour session the exercise intensity was maintained at 70-85% of maximal heart rate (monitored by sport-testers).

The aim of resistance training program was to enhance maximal strength as well as explosive power when possible. Each session consisted of a brief warm-up, followed by exercises strengthening major muscle groups. Within 2-3 workouts, the optimal weight was selected. This period gave the participants the opportunity to practice technique and experiment with different resistances. Strength training program was designed according to fundamental principles that ensure progressive overload of the musculature. Progress was made through increasing the amount of weight, increasing the number of repetitions and sets, decreasing the amount of rest time between sets, and a combination of any of these according to the individual's physical fitness. The exercises used standard free weights and equipment that can be found in most of the gyms. This approach allowed participants to become familiar with the beginner weight training workout routine that can be easy to follow after completion of the study.

Prior to and following the training, participants performed tests evaluating their neuromuscular performance. This study presents an effective functional performance testing for the overweight and obese, based on our research project findings. The test battery was adjusted according to experience and the results obtained, and complemented with other appropriate tests for the overweight and obese. Systems and methods developed at our department were utilized; however similar equipments produced by other companies are also available on the market. Customary tests used for assessment of endurance (e.g. Physical Working Capacity Test, Astrand cycle test, 2-min step in place test), strength and power (e.g. squat jump, countermovement jump, drop jump), speed and agility, balance or flexibility (sit and reach) are not described in the present study, but are available in specific papers.

Assessment of muscle strength and power

Maximum voluntary isometric contraction

Subjects perform three maximum voluntary isometric contractions while sitting in a fixed chair with their lower legs placed on a leg press machine platform with a knee angle of 90 degrees. They are carefully instructed to contract "as fast and forcefully as possible". On-line visual feedback of the instantaneous force is provided to the subject on a computer screen. Peak force, peak rate of force development (RFD) and RFD during time intervals of 0–100 and 0–200 ms are analyzed. These parameters are registered by means of the FiTRO Linear Isokinetic Dynamometer (FiTRONiC, SK). As an alternative, the FiTRO Force Plate can be used (FiTRONiC, SK).

Chair rising / Chair jumping

Subjects perform either chair rising or chair jumping tests. The chair is placed on a force plate and against a wall to stabilize it for safety. The subject sits in the middle of the seat, with their feet flat on the force plate, shoulder width apart. The arms are crossed and held on the chest. From the sitting position, subject either stand up completely (chair rising test), or jump as high as possible (chair jumping test). The subject is asked to perform the exercise with maximal effort in the concentric phase of lifting. Laboratory assistants stay next the subject to impede a possible fall. The better score of two trials is used for the analysis. The peak power and peak velocity of either chair rising or chair jumping are analysed.

To monitor the basic biomechanical parameters involved in both exercises, the FiTRO Force Plate (100 Hz sampling frequency) consisting of a strange gauge force plate, electronics, a 12 bit AD convertor, and software is used (FiTRONiC, SK). Basic software is used for calibration, data acquisition, storage and analysis (integral and average calculation from specified intervals, time zoom). An analytical software module is used for the calculation of acceleration, velocity, displacement and power from the force-time curve. Vertical force (F) applied to the plate consists of the weight (the product of body mass m and the gravitational constant g) and the inertia (the product of body mass and vertical acceleration) components.

Resistance exercises (bench press, squat, leg press, etc.)

In practice, strength and power produced at different velocities of muscle contractions are usually evaluated during bench press and squat, both without and with countermovement (CM) using maximal effort in the concentric phase of lifting [2]. For instance, an initial weight of 20 kg is increased by 10 kg or 5 kg (at higher loads) up to maximal power during bench presses. Rest intervals of 2 minutes is applied between particular reps. Best result of 3 trials (2 at higher loads) without and with countermovement is taken for the evaluation. Bench presses without CM begin from an initial position on the chest (the barbell about 0.05 m from the chest) and once achieved, subject holds the position for approximately 2 seconds before performing an upward movement on the command of the tester. Each subject is observed during the exercise to ensure that no countermovement is performed. The CM bench presses require the subject to lower the barbell to the chest without making contact when transitioning from the eccentric to concentric phase. Any repetitions that contacted the chest or failed to come within 0.05 m of the chest is disregarded and repeated after 1 minute of rest. Subjects are required to keep the same grip width for the entire testing protocol and to ensure that contact is maintenated between their hips and back with the bench. Barbell squats can be performed in a similar way or only with a weight determined as a % of previously established 1 repetition maximum (1RM). The selection of the weight is usually based on previous findings that identify the weight at which maximal power was achieved. Squats without CM begin from an initial semi squat position (90° knee flexion) regulated by visual inspection. Subjects are required to hold this position for approximately 2 seconds before performing the exercise (a squat or a jump, respectively) on the command of the tester. Each subject is observed during the exercise to ensure that no countermovement occurred. The range of the movement is also recorded in graphic and digital forms using the FiTRO Dyne Premium system. Squats with CM consist of an initial movement from full extension to a knee angle of 90°, followed immediately by an upward movement. A laboratory assistant stands behind the subject to prevent a possible fall. Rest intervals of 2 minutes are applied between reps. Better result of the two trials, for both exercises with and without countermovement, is taken for evaluation. However, our experience indicates that participants without resistance training experience are more effective at potentiating the power in the concentric phase of a jump rather than a squat while carrying an additional load. Therefore, jumps with body weight rather than squats holding a barbell on the back are preferred for power assessment, in spite of the fact that jumping provides more demand on balance and weight bearing forces than squatting.

However, muscle power can be evaluated also during other resistance exercises (e.g., leg press). As an example are shown knee extensions and knee flexions performed on weight stack machines [3]. Subjects seat in a comfortable position with the backrest angled at

100° to the seat. They hold their hands on the weight stack machine during the test. The range of movement is from 95º to 0° (anatomic 0) of knee extension and from 0° (anatomic 0) to 85° of knee flexion. They perform two tests: (1) maximal effort single repetitions of knee extension and knee flexion exercises with increasing weights, and (2) a set of 15 repetitions performed with the previously established weight at which the maximal power in test 1 was achieved. In the first test, subjects perform in random order two repetitions (one repetition using higher weights) of knee extension and knee flexion exercises with 5 kg stepwise increasing weights up to 1RM and a 30-second rest between the trials. The initial weight is fixed at 10 kg. Exercises are interspersed by 5 min rest period. The better score of two trials for each exercise is used for the analysis. In the second test, subjects perform 15 repetitions with the previously established weight at which maximal power has been achieved (e.g., a weight of 40 kg for knee extension and 30 kg for knee flexion). Subjects are verbally encouraged by the investigator to give their maximal effort. They are told to abort the test if they feel any discomfort or pain.

In order to simulate a lifting task, the deadlift to high pull and/or deadlift exercises can be applied [4]. Subjects perform two repetitions of deadlift and/ or deadlift to high pull with increased weights up to a maximal power. A rest interval of 2 minutes is applied between the individual sets. The greater of the two attempts is used for the analysis. Emphasis is placed on the proper technique for the exercises while using maximal effort in the lifting phase. Deadlift: The subjects stay with feet slightly apart in front of the bar as it rests on the ground. They bend forward at the waist with the chest forward and back arched. They grasp the bar with an overhand grip. Then they stand up straight, rotating the hips while keeping the abdominal muscles tight and with a slight arch of the back for support. This exercise contracts the deep spinal muscles on either side of the spinal column that straighten the spine. Straightening the torso by tilting the pelvis front to back contracts the gluteus maximus and hamstrings (except the short head of the biceps femoris). Deadlift to high pull: The subjects assume a hip-width stance with the knees slightly flexed and the toes pointed straight ahead. The grip is approximately shoulder-width. Then they lift the bar off the floor as high as possible, to about chin level. During the upward movement phase, the subjects are asked to keep their knees slightly flexed and the torso in a flat-back position. Two laboratory assistants stand behind the subject to impede possible falls.

During these resistance exercises, basic biomechanical parameters are monitored using the FiTRO Dyne Premium (FiTRONiC, SK). The system consists of a precise analogue rotary sensor connected to a reel. When pulling the tether (connected by a small hook to the barbell axis or weight stack machine), the reel is wound and the connected sensor measures the velocity. The rewinding of the reel is guaranteed by a string producing force of about 2 N. Signals from the sensor unit are AD converted (12 bit) and conveyed to a PC by means of a USB cable. Comprehensive software allows for the collection, calculation and on-line display of the basic biomechanical parameters involved in exercise. The system operates on Newton´s law of universal gravitation (force equals mass multiplied by the gravitational constant) and Newton´s law of motion (force equals mass multiplied by acceleration). The instantanous force when moving a barbell in the vertical direction is calculated as a sum of the gravitational force (mass multiplied by the gravitational constant) and the acceleration force (mass multiplied by acceleration). Acceleration of the vertical movements (positive or negative) is obtained as the derivation of the vertical velocity. Power is calculated as the product of force and velocity, and the actual position by integration of velocity. The device is placed on the floor and attached to the barbell axis or weight stack machine by a nylon tether. Subjects perform exercises while pulling a nylon tether on the device. Analysis is performed on peak and mean power in the acceleration and throughout the entire concentric phase of the lifting. Previous studies have demonstrated that evaluation of power output during resistance exercises using the FiTRO Dyne Premium system provides reliable data [5-7].

Assessment of speed and agility

Foot tapping

Tapping of upper and lower limbs in standing or sitting position is performed for 10 seconds. The number and frequency of the movement of lower limbs (f), contact time (Tc), and flight time (Tf) are monitored using the FiTRO Tapping Check (FiTRONiC, SK). The system consists of two contact switch mats connected by means of an USB interface to the computer and special software. The system measures 'contact' and 'flight' times in milliseconds, and calculates the cycle time and the corresponding tapping frequency for both legs, as well as separately, for both the right and left legs. The superior to average values of both legs from the two trials are utilized for the analysis. A previous study had identified that a foot tapping test is able to discriminate the tapping frequency of the lower limbs in groups of subjects of various ages and performance levels [8].

Agility

Subject perform the agility test. Their task is to touch, as quickly as possible, with either the left or the right foot, one of four mats located in the four corners outside of a pre-defined square. Mats have to be touched in accordance with the location of a stimulus in one of the corners of the screen. The test consists of pre-defined number of visual stimuli with random generation of their location on the screen and a time generation from 500 to 2500 ms. The result of the agility test is identified as the sum of previously determined numbers of agility times taken from the better of two trials.

Agility time is measured by means of the computer based system FiTRO Agility Check (FiTRONiC, SK). The system consists of contact switch mats connected by means of an interface to a computer. A special software measures the time the subject requires to accomplish foot contact with the mats, corresponding with the position of stimulus located in one of the four corners of the screen. Software enables storage, analyses and extensive reporting of the data. The reliability of the test procedure was previously verified and the testing protocol was standardized by the examination of 196 participants [9]. Analysis of repeated measurements showed a measurement error of 7.1%, which is within comparable range to common motor tests. A reference values of agility time for the comparison of subjects of particular ages can be found in book of Zemková and Hamar [10].

Simple and multi-choice reactions

Subjects respond to either one visual stimulus (simple reaction time) or more visual stimuli in the form of a circle, square, triangle or cross (2- or 4-choice reaction time) positioned on buttons on the table. The buttons have to be touched in accordance with the stimulus on the screen. Subjects are instructed to keep their hands as close as possible to the buttons in order to eliminate the influence of their hand movements on the outcome. They perform three trials of 40 responses on each test. Data from the best trial of simple RT and 2- or 4-choice RT are selected for the analysis.

Reaction times are measured using a diagnostic system FiTRO Reaction Check (FiTRONiC, SK) that consists of two buttons connected by means of an interface to a computer. A special software measures the time the subject requires to accomplish hand contact with the button, corresponding with the stimulus on the screen. Software enables storage, analysis and extensive reporting of the data.

Step initiation

Subjects perform 3 trials of (a) visually-triggered step initiation, (b) voluntary step, i.e. using their own initiative, (c) step with eyes closed, and (d) back step, in random order. They are instructed to perform each step as quickly as possible. They begin the step with the

Table 1. Proposed testing battery for the overweight and obese

ENDURANCE	
Tests	Parameters
PWC170 (Physical Working Capacity at a heart rate of 170 beats per minute) on a cycle ergometer	Power output (W) at a projected heart rate of 170 beats per minute (bpm)
2-min step in place test	Total number of times the right knee reaches the tape level in two minutes (1)
STRENGTH AND POWER	
Tests	Parameters
Maximum voluntary isometric contraction	Peak force (N)
	Peak rate of force development (N/s)
	Rate of force development during 0-100 ms (N/s)
	Rate of force development during 0-200 ms (N/s)
Chair rising / Chair jumping	Peak power (W)
	Peak power (W/kg)
	Peak velocity (m/s)
	Jump height (cm)
Bench presses with increasing weights	Mean power at each weight lifted (W)
	Maximal power at determined weight (W)
A set of 15 repetitions of bench presses	Fatigue index (%)
Deadlift to high pull	Peak power (W)
	Mean power (W)

SPEED AND AGILITY	
Tests	Parameters
Step initiation (visually-triggered, spontaneous)	Time of foot-off (ms)
	Time from foot-off to foot-contact (ms) and/or maximal velocity (m/s)
	Total CoP trajectory (mm)
	CoP trajectory in X-axis (mm)
	CoP trajectory in Y-axis (mm)
Hand / Foot tapping	Number (1)
	Contact time (ms)
	Flight time (ms)
	Frequency (Hz)
Agility	Total agility time (ms)
	Agility time in each direction of movement (ms)
Simple and multi-choice reactions	Total reaction time (ms)
	Reaction time from a defined number of reactions (ms)
	Number of correct / false responses in case of ≥2-choice RT (1)
BALANCE	
Tests	Parameters
Bipedal stance on force platform or foam surface placed on the platform with eyes open and eyes closed	Mean CoP velocity (mm/s)
	Mean distance from the middle of the CoP (mm)
	Mean trace length of the CoP in X-axis (mm)
	Mean trace length of the CoP in Y-axis (mm)
Visually-guided CoM tracking task	Mean CoP distance from horizontally flowing curve (mm)
	Mean CoP distance from vertically flowing curve (mm)
	Mean squared CoP distance from horizontally flowing curve (mm)
	Mean squared CoP distance from vertically flowing curve (mm)
Load release balance test	Time to peak anterior CoP displacement (ms)
	Peak anterior CoP displacement (mm)
	Time to peak posterior CoP displacement (ms)
	Peak posterior CoP displacement (mm)
	Time from peak anterior to peak posterior CoP displacement (ms)
	Total anterior to posterior CoP displacement (mm)
FLEXIBILITY	
Tests	Parameters
Sit and reach	Distance reached by the hand (cm or inches)

dominant leg while standing on a force plate covered by a contact mat. Time of foot-off and time from foot--off to foot-contact and/or velocity are monitored by means of the FiTRO Step Initiation Check (FiTRONiC, SK). Concurrently with the measurement of time and/or step velocity, real CoP trajectory and CoP trajectory in X-axis and Y-axis during step execution are registered. The force platform data are sampled at a frequency of 100 Hz. The best result of the 3 trials is utilized for analysis.

As an alternative, FiTRO Dyne Premium (FiTRONiC, SK) can be used to measure maximal step velocity [11]. A device is anchored to the wall and tethered by a nylon rope to the ankle of the subject. The subject is instructed to perform, as quickly as possible, the steps while pulling the nylon tether of the device. Data from the best of 3 trials are utilised for the analysis.

Assessment of balance

Static balance tests

Subjects stay barefoot on a force platform with their arms relaxed comfortably at their sides. They are instructed to stand in an upright posture with their feet abducted 10° and their heels separated mediolaterally by a distance of 6 cm. A series of two trials are conducted in random order under different conditions: bipedal stance on force platform with eyes open and closed, bipedal stance on foam surface placed on the force platform with eyes open and closed, and one-legged stance on force platform with eyes open. Each test consists of two 30-second trials while better result is taken for the evaluation.

Basic parameters of postural sway (mean CoP position in the X- and Y-axis, mean CoP velocity, mean CoP acceleration, mean trace length of the CoP, mean distance from the middle of the CoP, mean squared distance from the middle of the CoP, and area of trace of the CoP) are registered by using a system FiTRO Sway Check (FiTRONiC, SK). The force platform data is sampled at a frequency of 100 Hz. More information on reliability and methodological issues concerning the testing of postural stability under stable and unstable conditions can be found in related articles [12-16].

Task-oriented balance tests

Subjects perform either a visually-guided CoM tracking task or a visually-guided CoM target-matching task. In the first test, subjects are provided with feedback on the CoM displacement on a computer screen while standing on a force platform. Their task is to trace, by shifting their CoM, a curve flowing either in horizontal direction (regulation of CoM movement in Y-axis) or vertical direction (regulation of CoM movement in X-axis). The deviation of an instant CoP position from the curve is recorded at 100 Hz by means of the FiTRO Sway Check system (FiTRONiC, SK). In the second test, subjects have to hit the target randomly appearing in one of the corners of the screen by a horizontal CoM shift in the appropriate direction while standing on a spring-supported platform equipped with a computer-based system used for feedback monitoring of the CoM movement. The system registers the time, distance, and velocity of the CoP trajectory between the appearance of the stimulus and its being hit by a horizontal CoM shift. Analysis of repeated measurements showed reliability comparable to static balance tests [17], however with better potential for discriminating between groups with different level of balance capabilities [18] and revealing the training effects [19].

Load release balance test

Subjects are instructed to stand in an upright position with their feet abducted 10° and their heels separated mediolaterally at a distance of 6 cm. They stay barefoot on a force platform with their arms hold horizontally forward, a shoulder width apart. They are required to hold a bar in their hands with a 2 kg load fixed to the bar. A signal from the computer triggers a random release of the load over a 5 second period following the initiation of the test, thus the subject receives no cues as to when the perturbation would occur. The release of the load produces a sudden change in the external forces acting on the subject, leading to a small anterior and then a larger posterior displacement of the subject's centre of pressure (CoP). The perturbation after the load fall causes only a postural sway response, i.e. the subject do not need to take a step to maintain balance. The perturbation is quantified by the maximal anterior and posterior displacement, within one second after the load drop. The recording ends 2-3 seconds after the load-drop.

A series of three trials are conducted in random order under varied conditions: bipedal stance on force platform with eyes open and closed, bipedal stance on a foam surface placed on a force platform with eyes open and closed. The best result of each of the three trials is selected for evaluation. Peak anterior displacement of the subject´s CoP, the time to peak anterior displacement of the subject´s CoP, peak posterior displacement of the subject´s CoP, the time to peak posterior displacement of the subject´s CoP, total anterior to posterior displacement of the subject´s CoP, and the time from peak anterior to peak posterior displacement of the subject´s CoP, are registered by using the FiTRO Sway Check system, completed with a special program for Load Release Balance Test (FiTRONiC, SK). The force platform data is sampled at a frequency of 100 Hz.

Conclusions

Based on experience and results obtained, the testing battery was adjusted accordingly. Tests that provided redundant data were removed and others were inserted in order to assess complex neuromuscular performance in overweight and obese individuals. In the meantime, bench presses with increasing weights remain in the test battery to further assess their suitability. A set of 15 repetitions of bench presses for assessment of strength endurance may yet be included. Though no significant post-training changes in peak force and rate of force development were identified, the test of maximum voluntary isometric contraction may provide useful data and therefore has been included in the battery. As an alternative for jumping tests, chair rising and chair jumping were introduced. A deadlift to high pull simulating a lifting task has remained, whereas the deadlift was removed. Further, visually-triggered step initiation and/or spontaneous step initiation and foot tapping were included in the battery. Also, agility and reaction tests were added. All testing conditions of static balance remained; however the one-legged stance can be excluded in case of difficulty for the morbidly obese. For the load release balance test, it is sufficient to utilize the stance with eyes open, other conditions may be removed to save time. Additional information regarding postural control provides a visually-guided CoM tracking task. Tests of flexibility should be included in the battery.

Health and fitness professionals usually support assessment of physical performance related to specific training goals, such as improvement of the capability of cardiovascular system or strength and power. The objective is to evaluate the efficiency of the training and to design a program that will further increase the individual´s performance. However, less attention is paid to the assessment of fundamental abilities and skills, such as agility, speed of step execution, balance, core stability, posture and spinal mobility etc., when it is related to an untrained population with a predominant sedentary lifestyle. In order to fill this gap, we presented a testing battery for overweight and obese individuals utilizing mainly portable and inexpensive systems, which can also be conducted on sports fields. Its efficiency was verified during different training programs for this group, thus it could be implemented in the functional diagnostic for the overweight and obese as a complement to existing testing methods.

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UNIKALNY TEST ZDOLNOŚCI FUNKCJONALNYCH U OSÓB Z NADWAGĄ I OTYŁYCH

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Streszczenie

Pomimo dostępności wielu różnych testów oceniających funkcjonowanie układu nerwowo-mięśniowego u osób z określonymi potrzebami, wciąż w praktyce brakuje sprawdzonych metod oceny tego układu u osób z nadwagą i otyłością. Praca ta dostarcza efektywną i skuteczną czynnościową ocenę wyników badań u osób z tej grupy. W badaniu oceniono wpływ 3-miesięcznego treningu oporowego i aerobowego na poprawę sprawności układu mięśniowo-nerwowego u osób z otyłością i nadwagą. Interwencja zawierała testy wytrzymałościowe (test na ergometrze ze wzrastającym obciążeniem), testy siły i mocy (maksymalny dobrowolny skurcz izometryczny, podnoszenie krzesła, skok na krzesło, wyciskanie i rwanie ciężarów w obu przypadkach ze stopniowym wzrostem obciążeniem), testy szybkości poruszania się (wizualnie wyzwalane lub spontaniczne zapoczątkowanie chodu, stepowanie), testy równowagi (test równowagi z odciążeniem, badanie statyczne równowagi w różnych warunkach). Proponowane testy są czułe w ujawnianiu zmian potreningowych, a tym samym mogą być odpowiednie do zastosowania w diagnostyce czynnościowej tej populacji, jako element uzupełniający istniejące metody badawcze.

Słowa kluczowe: *funkcje układu nerwowo-mięśniowego, otyłość, testy, trening*

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