Determination of metabolic equivalents during low- and high-intensity resistance exercise in healthy young subjects and patients with type 2 diabetes

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ABSTRACT: The purpose of this study was to quantify the metabolic equivalents (METs) of resistance exercise in obese patients with type 2 diabetes (T2DM) and healthy young subjects and to evaluate whether there were differences between sessions executed at low- versus high-intensity resistance exercise. Twenty obese patients with T2DM (62.9±6.1 years) and 22 young subjects (22.6±1.9 years) performed two training sessions: one at vigorous intensity (80% of 1-repetition maximum (1RM)) and one at moderate intensity (60% of 1RM). Both groups carried out three strength exercises with a 2-day recovery between sessions. Oxygen consumption was continuously measured 15 min before, during and after each training session. Obese T2DM patients showed lower METs values compared with young healthy participants at the baseline phase (F= 2043.86; P<0.01), during training (F=1140.59; P<0.01) and in the post-exercise phase (F=1012.71; P<0.01). No effects were detected in the group x intensity analysis of covariance. In this study, at both light-moderate and vigorous resistance exercise intensities, the METs value that best represented both sessions was 3 METs for the obese elderly T2DM patients and 5 METs for young subjects.

INTRODUCTION

Strong evidence shows that physical inactivity increases the risk of many adverse health conditions. On the other hand, the many health benefits of physical activity are clearly documented [1], in particular, for obese subjects [2, 3], where their conditions reflect higher risk of development of type 2 diabetes [4]. More specifically, resistance training, which in turn produces similar enhancements in cardiovascular fitness, has also been recognized as a therapeutic tool in the management of type 2 diabetes (T2DM) by several trials [5-7] and reviews [8-10], with faster performance gains than with aerobic training. Thus resistance exercise continues to be evaluated in clinical and epidemiological studies with both healthy and T2DM patients [11, 12].

Despite the well-documented evidence of benefits from resistance training in several aspects of health and physical function, limited data are available on the energy cost of resistance exercise. Increasing caloric expenditure deriving from exercise training is an important parameter to consider in targeting T2DM, particularly for patients

who are morbidly obese and at higher risk of developing cardiovascular pathologies, when conducting robust randomised controlled trials, as suggested by the literature [13, 14]. The introduction of a systematic error in the MET estimation could provide a significant error in the calculation of total energy expenditure and potentially lead a misunderstanding in interpreting the study results, especially in those of long duration studies.

In the widely used compendium published by Ainsworth et al. [15, 16] the energy cost of many different modes and intensities of physical activities/exercise are reported. Since the introduction of the 1993 compendium [15], many studies have used the coding scheme and standard MET values to assign intensity levels to PA questionnaires globally [17]. The results from these studies have supported the conclusions that regular PA is health enhancing and that physical inactivity is a major risk factor for chronic diseases and premature mortality [1]. In this compendium, metabolic equivalents (METs) are

used to express energy expenditure; however, among the hundreds of activities, only 3 items appeared for the energy cost of resistance exercise: conditioning exercise – weightlifting (free weight, Nautilus, or Universal type), light or moderate effort, light workout, (3.0 METs); conditioning exercise – weightlifting (free weight, Nautilus, or Universal type), power lifting or bodybuilding, vigorous effort (6.0 METs); conditioning exercise – circuit training, general (8.0 METs). Thus, excluding circuit training and considering only the standardized resistance training that alternates a given number of repetitions (sets) with pauses (rest), we have a range of intensities expressed in METs that varies between light-moderate (3.0 METs) and vigorous (6.0 METs) and that quantifies the energy expenditure of resistance exercise. Another important issue concerns whether resistance exercise accurately reflects the caloric energy expenditure, in both long-term research studies and also in the clinical setting, where resistance exercise is part of the therapeutic treatment.

METs values are used for the duration of the training sessions, and not only for the duration of the sets; thus when analyzing data from long-term studies (e.g. one year) involving resistance exercise, it is important to assign to this kind of exercise the appropriate METs value, in order to avoid under- or over-estimation of the caloric expenditure. Typically, in long-duration studies [18-20] energy expenditure is calculated as the product of the duration (hours $\cdot$ times^{-1} $\cdot$ week^{-1}) of a given activity (e.g. resistance exercise) weighted by an estimate of METs of that activity, thus producing METs $\cdot$ h^{-1} $\cdot$ week^{-1}, and the introduction of a systematic error in the METs estimation could cause an important inaccuracy in the calculation of total energy expenditure and potentially lead to misinterpretation of the study results, especially for those of long duration.

In one attempt to quantify METs expenditure of a 12-month resistance training programme carried out at different intensities among obese-T2DM patients with metabolic syndrome, Zanuso et al. [21] estimated the same METs value at 60% of 1 maximal repetition (RM) and 80% of 1RM. These preliminary results suggest that in T2DM patients energy expenditure from resistance training exercise executed at both moderate and high intensity should be quoted as a 3 METs activity. In research and clinical practice where it is necessary to quantify the energy expenditure resulting from resistance training, the use of 3 or 6 METs can significantly change and invalidate the results. However, it was not clear if those results were due to the fact that participants were elderly, to the pathology itself or to other reasons.

To clarify this, we undertook the current study to evaluate if the METs values as proposed in the compendium reviews [16] are applicable to obese T2DM patients as well as to healthy young subjects when performing different resistance exercise sessions at 60% or 80% of their one repetition maximum (1RM).

MATERIALS AND METHODS

The research protocol was performed in the metabolic rehabilitation centre of the Metabolic Fitness Association (Monterotondo, Rome, Italy) in collaboration with the Department of Clinical Sciences at the University "La Sapienza" of Rome. Obese T2DM patients were recruited consecutively in one outpatient clinic and the inclusion criteria were the diagnosed T2DM plus at least 2 other metabolic syndrome traits, as defined according to the International Diabetes Association criteria [22]. Subjects who were diagnosed by a history of central nervous dysfunction such as hemiparesis, myelopathies, cerebral ataxia, significant musculoskeletal deformities (amputation, dysmetria or scoliosis) and abnormalities or arthritis limited movements by pain were excluded from participation. Additionally, a clinically evident history of severe cardiovascular disease, which could limit or contraindicate exercise, angina or related symptoms and postural hypotension (defined as a fall in arterial blood pressure when changing position of >20 mmHg in systole or > 10 mmHg in diastole) were also exclusion criteria. Young healthy participants were students recruited from the same department where this investigation was performed. All participants were recruited with at least 3 months of experience in resistance training techniques. Moreover, any condition that limited or contraindicated any phase of the research protocol led to exclusion from the protocol. Information on the purpose and procedures of the research were given to each subject, and written consent was obtained before participation. The study complied with the current laws of Italy for research on human participants and was examined and approved by the local ethic committee.

Experimental design

During the preliminary session, participants' anthropometric data were collected and subsequently they performed on non-consecutive days two resistance training sessions at different intensity (Table 1): moderate intensity (60% of 1RM) and vigorous intensity (80% of 1RM). As specified by Steele, we used "intensity" when referring to the degree or magnitude of a measurable characteristic or variable, in that case, the % of 1RM [23]. The vigorous intensity session was executed with 3 consecutive sets of 8 repetitions per muscular group, while moderate intensity sessions were performed with 2 consecutive sets of 15 repetitions per muscular group. For both intensity modalities, a moderate contraction velocity (1-2 s concentric phase; 1-2 s eccentric phase) was maintained. Exercise sets differed to equate energy expenditure across the two conditions. The recovery time between the series was set at 60 seconds while the time between two different exercises was 3 minutes. Both training intensities and exercise order were randomized to minimize the order effect of exercise intensity. Lower and upper limbs were alternated in order to avoid stress accumulation for the adjacent muscular groups in the upper limbs. This protocol was selected owing to the lack of resistance training experience for the majority of the participants, as suggested by the American College of Sports Medicine [24].

Testing procedures

Weight was measured using a BWB-800 AS scale (Tanita, Arlington Heights, IL) and height with a HR-200 stadiometer (Tanita, Arlington Heights, IL). To determine 1RM, 5 to 8 repetitions in the maximal

effort test were performed for the three specific exercises, then 1RM was predicted from the weight loaded and the number of repetitions executed using the Brzycki formula [25]. Strength tests were carried out with the following modalities: push movement on the transverse plane (Chest Press); lateral pull down on the frontal plane (Lat Machine with reverse grip); and leg press (Leg press). All machines were from Technogym (Cesena, IT). The active phase (concentric phase) lasted 2 seconds and 2 more seconds were needed for the passive phase of the movement (eccentric phase). Exercise was performed under supervision of an exercise physiologist [26]. All subjects were instructed to consume balanced meals (55% carbohydrate, 30% fat and 15% protein) starting two days before and during the actual experimental phase. Oxygen consumption was measured continuously from 15 minutes before to 15 minutes after the training session by means of a portable gas analyzer (Cosmed, Rome, IT) [27, 28]. The volumes were calibrated before each test using a 3-litre syringe (Model 5530, Hans Rudolf, Kansas City, MO), while gas analysis calibration was carried out through precisely determined reference gases. The analysis was divided into three phases: 1) Baseline with the subjects lying down quietly for 15 minutes; 2) Training, comprising 2 or 3 sets of 12 or 8 repetitions respectively plus the rest between sets. At the end of the last set, a rest of 60 seconds was considered, including the final one; 3) Post-exercise, with the subjects lying down quietly again for 15 minutes. Total oxygen consumption of each phase was then averaged to obtain $ml \cdot min^{-1} \cdot kg^{-1}$ and the latter divided by 3.5 to obtain METs. For each subject, correct technique was monitored during each repetition to ensure that exercise execution was held constant during all the sets and between the two different training days.

Statistics

Statistical analysis was carried out using SPSS (SPSS 18.0 for Windows, SPSS Inc., Chicago, IL). Results were expressed as means ± standard deviation (SD). The Kolmogorov-Smirnov (K-S) test was performed to check if data were normally distributed. A series of mixed-model two-way repeated measures analyses of covariance (ANCOVA) across groups and intensities (for baseline, training and post-exercise values), with weight and age as covariates, was used to detect the main effect for groups. Paired samples t test was performed to compare the within-group effect from the different intensities of exercise. The significance level was set at p = 0.05.

RESULTS

Twenty obese subjects (11 males and 9 females; age 62.9 ± 6.1 years), obese (BMI 33.9 ± 7.07) with T2DM (~11.4 ± 4.8 years from the diagnosis of diabetes) and 22 young healthy individuals (7 males and 15 females, age 22.6 ± 1.9 years, BMI 23.4 ± 2.3) were recruited. K-S test indicated a normal distribution for all data, while covariates appearing in the ANCOVA mixed model were evaluated as follows: age = 41.85 years and weight = 76.04 kg. No interactions between covariates and METs values were found.

In within-group analyses at baseline, training and post-exercise phases, no significant differences occurred in METs intensities (Table 2 and Table 3).

When examining the group effect, obese type 2 diabetes patients showed lower METs values at the baseline phase (F= 2043.86; P<0.01), during training (F=1140.59; P<0.01) and in the post-exercise phase (F=1012.71; P>0.01). No significant effects were detected in the group x intensity analysis of covariance (Figure 1).

TABLE I. Characteristics of participants.

	Obese type 2 diabetes patients n = 20	Young subjects n = 22	P value
Men / Women	11/9	7/15	0.85
Age (years)	62.9 ± 6.1	22.6 ± 1.9	< 0.01
Weight (kg)	81.3 ± 16.8	71.2 ± 18.8	< 0.01
BMI, $kg \cdot m^{-2}$	33.9 ± 7.1	23.4 ± 2.3	< 0.01
Diabetes duration (years)	11.4 ± 4.8	-	-
HbA1c (%)	7.3 ± .6	-	-
1RM Lat Pull Down (kg)	24.0 ± 7.5	83.9 ± 25.5	< 0.01
1RM Chest Press (kg)	25.7 ± 10.6	82.7 ± 30.2	< 0.01
1RM Leg Press (kg)	85.6 ± 57.6	230.1 ± 66.3	< 0.01
60% of 1RM Lat Pull Down overall load lifted (kg)	432.1 ± 135.6	1510.2 ± 460.5	< 0.01
80% of 1RM Lat Pull Down overall load lifted (kg)	461.1 ± 144.6	1611.1 ± 491.2	< 0.01
60% of 1RM Chest Press overall load lifted (kg)	462.71 ± 190.8	1489.5 ± 544.7	< 0.01
80% of 1RM Chest Press overall load lifted (kg)	493.6 ± 203.5	1588.8 ± 581.1	< 0.01
60% of 1RM Leg Press overall load lifted (kg)	1542.1 ± 1036.9	4140.9 ± 1193.7	< 0.01
80% of 1RM Leg Press overall load lifted (kg)	1644.9 ± 1106.1	4416.9 ± 1273.3	< 0.01

Note: Values are mean ± SD, BMI = body mass index, HbA1c = glycated haemoglobin, 1RM = 1 maximum repetition. P values refer to the results of paired samples t tests.

TABLE 2. Metabolic equivalents (METs) at baseline, during exercise and post-exercise phases.

METs values	Obese T2DM patients			Young subjects		
	60% 1RM	80% 1RM	P value	60% 1RM	80% 1RM	P value
Baseline [a]	1.07 ± 0.1	1.09 ± 0.1	0.67	1.31 ± 0.2	1.34 ± 0.2	0.61
Exercise [b]	3.00 ± 0.5	3.13 ± 0.7	0.34	4.99 ± 0.8	5.01 ± 0.8	0.92
Post-exercise [c]	1.37 ± 0.3	1.28 ± 0.2	0.16	1.90 ± 0.3	1.84 ± 0.3	0.28

Note: MET = metabolic equivalent, 1RM = 1 maximum repetition, T2DM = type 2 diabetes mellitus patients. P values are referred to the results of paired samples t tests. Values are mean ± SD. P values represent the results of the within-group comparisons which where performed through paired-sample t tests.
[a] Baseline data are the average of the last five minutes of 15 minutes of quite rest recorded before the training session.
[b] Exercise: average METs of the resistance exercise component of the session.
[c] Post-exercise data: average of the last five minutes of 15 minutes of quiet rest measured after the training session.

TABLE 3. Relative and absolute VO2 values measured during the resistance exercise at 60% and 80% of 1RM.

METs values	Obese T2DM patients			Young subjects		
	60% 1RM	80% 1RM	P value	60% 1RM	80% 1RM	P value
Relative VO$_2$ (ml$\cdot$kg$^{-1}\cdot$min^{-1})	8.14 ± 2.3	8.44 ± 1.7	0.75	15.05 ± 2.6	15.56 ± 2.8	0.77
Absolute VO$_2$ (L$\cdot$min^{-1})	0.55 ± 0.1	0.67 ± 0.2	0.62	0.98 ± 0.3	1.01 ± 0.3	0.93

Note: VO$_2$ = oxygen consumption, 1RM = 1 maximum repetition, T2DM = type 2 diabetes mellitus patients. P values refer to the results of paired samples t tests. Values are mean ± SD, averages of the resistance exercise component of the session.
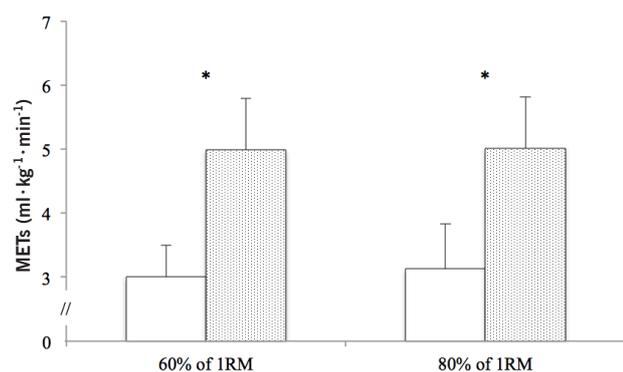

FIG. I. Exercise intensities measured in METs for type 2 diabetes patients (white columns) and young subjects (dotted columns) during exercise at 60% and 80% of 1 maximal repetition (1RM). * describes the effect of group (young subjects vs. obese T2DM patients) on energy expenditure.

DISCUSSION

Various aspects related to the caloric cost of resistance exercise have been previously examined, such as the effects of different intensities on post-exercise oxygen consumption [29, 30] or the effect of strength training on resting metabolic rate [31, 32]. The energy cost of resistance exercise executed with different modalities was also analyzed (e.g. standard vs. super slow repetition) [33, 34]. One of the few studies that have analyzed energy expenditure of resistance exercise in adults, with similar age characteristics as our sample, was that of De Groot et al. [35]; however, that study was conducted in patients with cardiovascular disease, and the type of exercise was multiple-circuit training; for that reason, direct comparisons with the present study are difficult due to major differences in population, protocol and specific resistance exercise modality. To the best of our knowledge, the studies that experimentally better investigated the energy cost of resistance exercises executed at different intensities are those published by Phillips & Ziuraitis [36, 37], which with a portable gas analyzer evaluated the energy cost of a single set resistance exercise protocol as expressed in METs. In one study [36] 6 young males and 6 young females (mean age 26.7 years) performed 1 set of 15 repetition maximum (15-RM) for each of eight selected resistance exercises; the results showed that the energy cost of this activity expressed in METs was 3.9 and 4.2 for young men and women respectively. In a later study [37], using the same protocol with an elderly population (5 men and 5 women; mean age 73.1 years) METs intensities were and 3.3 and 3.0 men and women respectively. However, even though those studies showed that between young and older subjects there exists a difference in the energy cost of a resistance exercise session executed at the same relative intensity, METs values of resistance exercise executed at different intensities were not investigated.

Comparing the results of the present study with those of Phillips et al. [36, 37], the energy cost expressed in METs seems comparable, since in both studies the results yielded approximately 3 METs in both men and women. The intensity of 3 METs corresponds to the light-moderate category as reported in the 'compendium' review but if in the study of Phillips the intensity was moderate, since 15 RM corresponds approximately to 60% of 1RM, in the present study the intensity of 3 METs was obtained at both 60% and 80% of 1RM. However, with young subjects, the studies are not in agreement,

since that by Phillips yielded approximately 4 METs at 60% of 1RM, while in our study at both intensities young subject revealed 5 METs with no statistical differences between the two intensities.

This study suggests that the indications presented in the widely used compendium [16], where 'light-moderate' resistance training is quoted as 3 METs, and 'Vigorous' resistance training is quoted as 6 METs, should be considered carefully. Those differences between obese T2DM patients and young subjects can be explained firstly considering the low baseline strength values of the diabetes participants: the percentages at 60% and 80% of those low baseline values required loads to be lifted that were quite similar among groups, thus creating a floor effect not allowing differences to be detected. Furthermore, as stated by Scott and Earnest [38], lifting a weight to muscular failure can entail significantly greater aerobic, anaerobic and recovery EE components as compared to non-fatiguing lifting. In that view, the floor effect could have been also reduced the difference in muscular failure during 60% and 80% intensities. Secondly, it is well known that different ratios (and load, in this case, can have influenced it) in the force-velocity relationship should belong, by definition, to a difference in the number of recruited motor units [39]; thus the amount of weight lifted would determine how much tissue is stimulated. In less trained and older subjects however, due to more shortened motor units, different training loads, especially if their difference is not so marked in relative (percentages of 1RM) and absolute terms (the lifted weight), they could target the same motor units [21]. Motor unit activation is primarily dependent on the degree of effort and not the absolute amount of resistance when performing an exercise. However, the degree of effort and motor unit activation required for optimal strength gains is unknown [40]. On the other hand, if the above explanation is correct, in young subjects expressing higher maximal values, and not having compressed motor units, differences in METs intensity could be easily detected, but it was not the case, since no statistically significant differences were detected between the two intensities.

Limitations of this study

The actual resistance exercise was only a part of the total time during which METs were being measured for either moderate or vigorous intensities; part of the time during which oxygen consumption was sampled was non-exercise time, so any small differences in work done during the resistance exercise could not be discerned using the methods adopted to measure oxygen consumption; thus what was measured consisted in the total amount of energy deriving from the resistance exercise session (repetitions plus rest) and not only that of the actual resistance exercise. If, from a side, that effect could be considered as a limitation, from a metabolic point of view, with the absence of a steady state, oxygen uptake peaks in the recovery/rest periods between weight lifting sets, not during the exercise itself [41]. Active phases of exercise plus recovery periods can be more reliable when calculating the energy expenditure.

Furthermore, in this study the participants performed only three resistance exercises, whilst a training session based on resistance training only would require more than three exercises. We decided to study only three exercises for a technical reason related to the difficulty in wearing the mask of the gas analyzer for a longer time, especially with the elderly. On the other hand, diabetic patients typically perform a combined aerobic and resistance exercise session and more rarely a resistance training session only. Thus the three exercises can represent the resistance training part within a typical training session constituted by aerobic and resistance components. Another limitation of this study could be attributed to the resting time between the 2 days of training. In fact, obese T2DM participants, who were randomly assigned to perform the 80% 1RM session before the 60% one, were also older than their counterparts, so they could have needed more than 2 days to fully recover from the previous session.

CONCLUSIONS

Our data reveal that in both obese T2DM patients and young subjects, the intensity of a resistance exercise session required, from a metabolic point of view, the same number of METs. Hence, the standards presented in the widely used compendium published by Ainsworth et al. [16], where 'light-moderate' resistance training is quoted at 3 METs, and 'vigorous' resistance training is quoted at 6 METs, do not seem applicable in both obese diabetic patients and young subjects.

In this study, at both light-moderate and vigorous resistance exercise intensities, the METs value that best represented both sessions was 3 METs for the obese T2DM patients and 5 METs for young subjects. This study does not provide a definitive conclusion to explain whether the differences between the two groups depends on age, diabetes, BMI or other causes. However, long-duration studies aimed at quantifying the caloric expenditure of exercise deriving from resistance exercise should apply carefully the current METs codes reported in the compendium review, when quoting resistance exercise executed at light-moderate and vigorous intensities.

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REFERENCES

1. Physical Activity Guidelines Advisory Committee report. US Department of Health and Human Services; 2008.
2. Bishop-Bailey D. Mechanisms governing the health and performance benefits of exercise. Br J Pharmacol. 2013;170:1153-66.
3. Swift DL, Johannsen NM, Lavie CJ, Earnest CP, Church TS. The role of exercise and physical activity in weight loss and maintenance. Prog Cardiovasc Dis. 2014;56:441-7.
4. Freemantle N, Holmes J, Hockey A, Kumar S. How strong is the association between abdominal obesity and the incidence of type 2 diabetes? Int J Clin Pract. 2008;62:1391-6.
5. Castaneda C, Layne JE, Munoz-Orians L, Gordon PL, Walsmith J, Foldvari M, et al. A randomized controlled trial of resistance exercise training to improve

glycemic control in older adults with type 2 diabetes. Diabetes Care. 2002;25:2335-41.

6. Fenicchia LM, Kanaley JA, Azevedo JL, Jr., Miller CS, Weinstock RS, Carhart RL, et al. Influence of resistance exercise training on glucose control in women with type 2 diabetes. Metabolism. 2004;53:284-9.

7. Ibanez J, Izquierdo M, Arguelles I, Forga L, Larrion JL, Garcia-Unciti M, et al. Twice-weekly progressive resistance training decreases abdominal fat and improves insulin sensitivity in older men with type 2 diabetes. Diabetes Care. 2005;28:662-7.

8. Umpierre D, Ribeiro PA, Kramer CK, Leitao CB, Zucatti AT, Azevedo MJ, et al. Physical activity advice only or structured exercise training and association with HbA1c levels in type 2 diabetes: a systematic review and meta-analysis. JAMA. 2011;305:1790-9.

9. Zanuso S, Jimenez A, Pugliese G, Corigliano G, Balducci S. Exercise for the management of type 2 diabetes: a review of the evidence. Acta Diabetol. 2010;47:15-22.

10. Praet SF, van Loon LJ. Exercise therapy in type 2 diabetes. Acta Diabetol. 2009;46:263-78.

11. Balducci S, Sacchetti M, Orlando G, Salvi L, Pugliese L, Salerno G, et al. Correlates of muscle strength in diabetes: The study on the assessment of determinants of muscle and bone strength abnormalities in diabetes (SAMBA). Nutr Metab Cardiovasc Dis. 2014;24:18-26.

12. Mann S, Beedie C, Balducci S, Zanuso S, Allgrove J, Bertiato F, et al. Changes in insulin sensitivity in response to different modalities of exercise: a review of the evidence. Diabetes Metab Res Rev. 2014;30:257-68.

13. Sukala WR, Page R, Cheema BS. Exercise training in high-risk ethnic populations with type 2 diabetes: a systematic review of clinical trials. Diabetes Res Clin Pract. 2012;97:206-16.

14. Sukala WR, Page R, Rowlands DS, Krebs J, Lys I, Leikis M, et al. South Pacific Islanders resist type 2 diabetes: comparison of aerobic and resistance training. Eur J Appl Physiol. 2012;112:317-25.

15. Ainsworth BE, Haskell WL, Leon AS, Jacobs DR, Jr., Montoye HJ, Sallis JF, et al. Compendium of physical activities: classification of energy costs of human physical activities. Med Sci Sports Exerc. 1993;25:71-80.

16. Ainsworth BE, Haskell WL, Whitt MC, Irwin ML, Swartz AM, Strath SJ, et al. Compendium of physical activities: an update of activity codes and MET

intensities. Med Sci Sports Exerc. 2000;32:S498-504.

17. Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett DR, Jr., Tudor-Locke C, et al. 2011 Compendium of Physical Activities: a second update of codes and MET values. Med Sci Sports Exerc. 2011;43:1575-81.

18. Balducci S, Zanuso S, Massarini M, Corigliano G, Nicolucci A, Missori S, et al. The Italian Diabetes and Exercise Study (IDES): design and methods for a prospective Italian multicentre trial of intensive lifestyle intervention in people with type 2 diabetes and the metabolic syndrome. Nutr Metab Cardiovasc Dis. 2008;18:585-95.

19. Di Loreto C, Fanelli C, Lucidi P, Murdolo G, De Cicco A, Parlanti N, et al. Make your diabetic patients walk: long-term impact of different amounts of physical activity on type 2 diabetes. Diabetes Care. 2005;28:1295-302.

20. Tanasescu M, Leitzmann MF, Rimm EB, Willett WC, Stampfer MJ, Hu FB. Exercise type and intensity in relation to coronary heart disease in men. JAMA. 2002;288:1994-2000.

21. Zanuso S, Balducci S, Gutierrez AJ, Bergamin M, Pugliese G. Similar energy expenditure from resistance training at moderate and vigorous intensity in subjects with type 2 diabetes. Diabetes Res Clin Pract. 2009;85:e40-1.

22. Alberti KG, Zimmet P, Shaw J, Group IDFETFC. The metabolic syndrome--a new worldwide definition. Lancet. 2005;366:1059-62.

23. Steele J. Intensity; in-ten-si-ty; noun. 1. Often used ambiguously within resistance training. 2. Is it time to drop the term altogether? Br J Sports Med. 2014;48:1586-8.

24. American College of Sports M. American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. Med Sci Sports Exerc. 2009;41:687-708.

25. Brzycki M. Strength testing - prediction a one-rep max from preps to fatigue. J Phys Educ Recreation Dance. 1993;64:88-90.

26. Cheema BS, Robergs RA, Askew CD. Exercise physiologists emerge as allied healthcare professionals in the era of non-communicable disease pandemics: a report from australia, 2006-2012. Sports Med. 2014;44:869-77.

27. Nieman DC, Austin MD, Benezra L, Pearce S, McInnis T, Unick J, et al. Validation of Cosmed's FitMate in measuring oxygen consumption and estimating resting metabolica rate. Res Sports Med. 2006;14:89-96.

28. Nieman DC, Lasasso H, Austin MD, Pearce S, McInnis T, Unick J. Validation of Cosmed's FitMate in measuring

exercise metabolism. Res Sports Med. 2007;15:67-75.

29. Kang J, Hoffman JR, Im J, Spiering BA, Ratamess NA, Rundell KW, et al. Evaluation of physiological responses during recovery following three resistance exercise programs. J Strength Cond Res. 2005;19:305-9.

30. Olds TS, Abernethy PJ. Postexercise oxygen consumption following heavy and light resistance exercise. J Strength Cond Res. 1993;7:142-52.

31. Broeder CE, Burrhus KA, Svanevik LS, Wilmore JH. The effects of either high-intensity resistance or endurance training on resting metabolic rate. Am J Clin Nutr. 1992;55:802-10.

32. Lemmer JT, Ivey FM, Ryan AS, Martel GF, Hurlbut DE, Metter JE, et al. Effect of strength training on resting metabolic rate and physical activity: age and gender comparisons. Med Sci Sports Exerc. 2001;33:532-41.

33. Hunter GR, Seelhorst D, Snyder S. Comparison of metabolic and heart rate responses to super slow vs. traditional resistance training. J Strength Cond Res. 2003;17:76-81.

34. Kuehl K, Eliot DI, L. G. Predicting caloric energy expenditure during multi-station resistance exercise. J Appl Sport Sci Res. 1990;4:63-7.

35. DeGroot DW, Quinn TJ, Kertzer R, Vroman NB, Olney WB. Circuit weight training in cardiac patients: determining optimal workloads for safety and energy expenditure. J Cardiopulm Rehabil. 1998;18:145-52.

36. Phillips WT, Ziuraitis JR. Energy cost of the ACSM single-set resistance training protocol. J Strength Cond Res. 2003;17:350-5.

37. Phillips WT, Ziuraitis JR. Energy cost of single-set resistance training in older adults. J Strength Cond Res. 2004;18:606-9.

38. Scott CB, Earnest CP. Resistance Exercise Energy Expenditure is Greater with Fatigue as Compared to Non-Fatigue. Journal of Exercise Physiology online. 2011;14:1-11.

39. Meijer JW, Lange F, Links TP, van der Hoeven JH. Muscle fiber conduction abnormalities in early diabetic polyneuropathy. Clin Neurophysiol. 2008;119:1379-84.

40. Carpinelli RN. A Critical Analysis of a Review on Strength Training in the Military. Journal of Exercise Physiology online. 2013;16:70-81.

41. Scott CB. Oxygen Costs Peak after Resistance Exercise Sets: A Rationale for the Importance of Recovery over Exercise. Journal of Exercise Physiology online. 2012;15:1-8.