



Fisher, James. (2012). Attempting to better define "intensity" for muscular performance: is it all wasted effort? *European Journal of Applied Physiology*, September 2012, 112 (12), pp. 4183-4185

Downloaded from <http://ssudl.solent.ac.uk/2273/>

Usage Guidelines

Please refer to usage guidelines at <http://ssudl.solent.ac.uk/policies.html> or alternatively contact ir.admin@solent.ac.uk.

*Attempting to better define “intensity”
for muscular performance: is it all wasted
effort?*

J. Fisher & D. Smith

**European Journal of Applied
Physiology**

ISSN 1439-6319

Eur J Appl Physiol
DOI 10.1007/s00421-012-2463-0



Your article is protected by copyright and all rights are held exclusively by Springer-Verlag Berlin Heidelberg. This e-offprint is for personal use only and shall not be self-archived in electronic repositories. If you wish to self-archive your work, please use the accepted author's version for posting to your own website or your institution's repository. You may further deposit the accepted author's version on a funder's repository at a funder's request, provided it is not made publicly available until 12 months after publication.

Attempting to better define “intensity” for muscular performance: is it all wasted effort?

J. Fisher · D. Smith

Received: 2 May 2012 / Accepted: 13 July 2012
© Springer-Verlag Berlin Heidelberg 2012

Dear Editor,

We read with interest the recent publication “Muscle activations under varying lifting speeds and intensities during bench press” (Sakamoto and Sinclair 2012). In the title and throughout this paper, the term *intensity* is used. We suggest that this usage is inaccurate, both here and more widely, with reference to the percentage of one repetition maximum (%1RM), e.g. the higher the %1RM, the higher the *intensity* (Sakamoto and Sinclair 2012). However, %1RM is simply a reference to load. Authors have attempted to justify this use (e.g. Fry 2004; Willardson and Burkett 2008) by pointing out that intensity is a common term for %1RM. A major problem with this argument is the inability of this term to accommodate effort, load, repetitions, inter-individual genetic influences such as muscle fiber type and repetition duration. This letter intends to address these issues and more accurately define potentially confusing terminology.

Effort

Within the area of cardiovascular or aerobic exercise, *intensity* is generally considered to represent the effort required by the body at a given velocity, incline, and

resistance (or other variable) at a given work rate and is typically expressed relative to quantities such as heart rate (HR), % of heart rate maximum (HRM), blood lactate (BLa) or oxygen uptake (VO_2). With regard to muscular effort, however, the percentage of 1RM is purely a representation of load. Whilst increasing or decreasing a given load might indeed require greater or lesser effort, it should never be considered a measure of the effort or intensity that the body is working at. It is surely not acceptable that terminology can be used with different meanings based on differing modalities of exercise being performed.

Repetitions

Under the present definition, any number of people completing the same number of repetitions at the same %1RM (i.e. at the same relative loads) is deemed to be working at a measurably identical effort level. This is incorrect. Hoeger et al. (1987, 1990) and Shimano et al. (2006) reported 1RM values and respective RMs for given %1RM for male and female, trained and untrained participants, and their data show large variations in the number of repetitions possible for the same %1RM between participants.

Shimano et al. (2006) also highlighted that at the same load (60 % 1RM) there were significant differences for trained persons between the number of repetitions possible between squat (8.8 ± 0.7), bench press (7.0 ± 1.7) and arm curl (6.4 ± 2.0) exercises. Thus, even at the same relative load, a single person appears to respond differently to these different exercises. For example, based on the data by Shimano et al. (2006) six repetitions at a load of 60 % 1RM might induce a lower effort level for a squat exercise than for an arm curl exercise. Thus, they cannot be considered the same *intensity*. In fact, Shimano et al. (2006)

Communicated by Susan A. Ward.

J. Fisher (✉)
Department of Health, Exercise and Sport Science,
Southampton Solent University, East Park Terrace,
Southampton SO14 0YN, UK
e-mail: James.fisher@solent.ac.uk

D. Smith
Manchester Metropolitan University, Crewe, UK

also recorded ratings of perceived exertion (RPE), reporting no significant differences between maximal repetitions to failure for 60, 80, and 90 % 1RM for arm curl and bench press. Thus, when performed to muscular failure, regardless of load, each exercise was of the same *intensity*. Interestingly, the authors did find a significantly higher RPE for 60 % 1RM for the squat exercise when compared to 80 and 90 % 1RM. If perceived exertion is scored higher at a lower load, then quite simply; how can 80 or 90 % 1RM be considered a higher *intensity* than 60 % 1RM?

We might also consider muscle fiber type (Douris et al. 2006), motor unit recruitment and firing patterns (Sale 1987; Westing et al. 1991), mechanical efficiency (Nelson et al. 2011), and limb length (Miller et al. 1993), which can all affect maximal and sustained force production. This means that the knowledge of a person's 1RM for a given muscular load does not provide any accurate basis for prediction of how many repetitions that person can perform at any given %1RM, let alone could it be generalised across other exercises or groups of individuals.

Repetition duration

Finally we might also consider the effects of repetition duration (commonly and incorrectly cited as *speed*; e.g. Sakamoto and Sinclair 2012). Speed, by definition is a product of the time taken to move a given distance. This is confirmed by the units used to measure speed, e.g. meters or centimeters/second (m/s, cm/s) in linear movement, or degrees/second ($^{\circ}$ /s) in rotational movement. Consider a study where the participants perform a free-weight exercise and are controlled for repetition duration (e.g. 2 s concentric:2 s eccentric) but not controlled for range of motion. We can assume that there might be some, albeit minor, disparity between participants in the distance the weight is moved. However, if participant (a.) moves the weight a greater distance at the same repetition duration as participant (b.), then it is evident that participant (a.) actually moved the weight at a higher *speed* (e.g. a greater distance in the same time).

Researchers considering repetition duration have reported that, when performed to muscular failure, a greater number of repetitions are possible at lower repetition durations (Lachance and Hortobagyi 1994; Morrissey et al. 1998; Sakamoto and Sinclair 2006). Thus, at longer repetition durations, a lower number of repetitions are likely, suggesting that the force requirement and fatigue are greater. Indeed, a recent study considering submaximal exercise (3 sets of 5 repetitions at 70 % 1RM) reported significantly higher anaerobic-, and total-energy expenditure for participants when performing longer (5 s) compared to shorter (3 s) repetitions (Scott 2012). Based on the

evidence, repetition duration clearly interacts with the *intensity* of exercise; e.g. moving two identical loads at different repetition durations would require a differing amount of energy and effort, and thus *intensity*.

Interestingly, Sakamoto and Sinclair (2012) state that they did measure vertical bar displacement using a string potentiometer, with an absolute error of less than or equal to 1 mm. However, it is unclear as to whether this was used to control or maintain the distance the bar was moved for each repetition, between participants, or simply to measure the speed. Either way it is unfortunate that the authors do not make mention of the distance the bar was moved by each participant (presuming they were not identical), and that the authors then repeat the earlier inaccuracy of using the term *speed* to represent the repetition duration (e.g. 5.6, 2.8, and 1.9 s).

Amidst this confusion in terminology, we can assume that 1RM is the maximal effort and thus maximal *intensity*, which presumably is from where %1RM has been derived as an incorrect measure of relative intensity. However, the evidence presented shows that below maximal (e.g. <1RM) any %1RM immediately becomes a representation of the relative load used, and only the load used; not the relative intensity of the participant.

Ultimately the misuse of the term *intensity* represents a plethora of potential complications and inadequacies in research, where in reality use of the term *load* would resolve any complications, and provide a more scientifically accurate definition. *Intensity*, within resistance training, is simply the 'level of effort applied to a given load'. Previously authors (e.g. Carpinelli et al. 2004; Fisher et al. 2011) have suggested this amendment but apparently the efforts to change this paradigm have not been widely enough accepted. Perhaps authors, editorial boards, reviewers and readers, as well as members and coordinators of associations such as the American College of Sports Medicine (ACSM), National Strength and Conditioning Association (NSCA) and other scientists might consider the accuracy and use of this terminology in the future.

Conflict of interest The authors are not aware of any conflicts of interest.

References

- Carpinelli R, Otto RM, Winett RA (2004) A critical analysis of the ACSM position stand on resistance training: insufficient evidence to support recommended training protocols. *J Exerc Physiol* 7:1–60
- Douris PC, White BP, Cullen RR et al (2006) The relationship between maximal repetition performance and muscle fibre type as estimated by non-invasive techniques in the quadriceps of untrained women. *J Strength Cond Res* 20:699–703
- Fisher J, Steele J, Bruce-Low S, Smith D (2011) Evidence-based resistance training recommendations. *Med Sport* 15(3):147–162

- Fry AC (2004) The role of resistance exercise intensity on muscle fibre adaptations. *Sports Med* 34:663–679
- Hoeger WW, Barette SL, Hale DF et al (1987) Relationship between repetitions and selected percentages of one-repetition maximum. *J Appl Sport Sci Res* 1:11–13
- Hoeger WW, Hopkins DR, Barette SL et al (1990) Relationship between repetitions and selected percentages of one-repetition maximum: a comparison between untrained and trained males and females. *J Strength Cond Res* 4:46–54
- Lachance PF, Hortobagyi T (1994) Influence of cadence on muscular performance during push-up and pull-up exercises. *J Strength Cond Res* 8:76–79
- Miller AEJ, MacDougall JD, Tarnopolsky MA, Sale DG (1993) Gender differences in strength and muscle fiber characteristics. *Eur J Appl Physiol Occup Phys* 66(3):254–262
- Morrissey MC, Harman EA, Frykman PN et al (1998) Early phase differential effects of slow and fast barbell squat training. *Am J Sports Med* 26:221–230
- Nelson FE, Ortega JD, Jubrias SA et al (2011) High efficiency in human muscle an anomaly and an opportunity? *J Exp Biol* 214:2649–2653
- Sakamoto A, Sinclair PJ (2006) Effect of movement velocity on the relationship between training load and the number of repetitions of bench press. *J Strength Cond Res* 20:523–527
- Sakamoto A, Sinclair PJ (2012) Muscle activations under varying lifting speeds and intensities during bench press. *Eur J Appl Physiol* 112:1015–1025
- Sale DG (1987) Influence of exercise and training on motor unit activation. *Exerc Sport Sci Rev* 15:95–151
- Scott CB (2012) The effect of time-under-tension and weight lifting cadence on aerobic, anaerobic, and recovery energy expenditures: 3 submaximal sets. *Appl Physiol Nutr Metab* 37:252–256
- Shimano T, Kraemer WJ, Spiering BA et al (2006) Relationship between the number of repetitions and selected percentages of one-repetition maximum in free weight exercises in trained and untrained men. *J Strength Cond Res* 20:819–823
- Westing SH, Cresswell AG, Thorstensson A (1991) Muscle activation during maximal voluntary eccentric and concentric knee extension. *Eur J Appl Physiol* 62:104–108
- Willardson JM, Burkett LN (2008) The effect of different rest intervals between sets on volume components and strength gains. *J Strength Cond Res* 22:146–152