Advances in Physical Education, 2022, 12, 372-388
https://www.scirp.org/journal/ape
ISSN Online: 2164-0408
ISSN Print: 2164-0386

Using a Multidimensional Motivation's Scale during Effort to Understand How Motivation Evolves with Intensity and Fatigue

Bertrand Baron[1,2*], **Alain Groslambert**[2], **Frederic Grappe**[2,3]

[1]ESPACE-DEV, Université Montpellier, IRD, Université Antilles, Université Guyane, Université Réunion, Montpellier, France
[2]Laboratoire C3S Culture, Sport Santé, Société, EA 4660, Université de Bourgogne Franche-Comté, Besançon, France
[3]Equipe Cycliste Groupama-FDJ, France
Email: *bertrand.baron@univ-reunion.fr

How to cite this paper: Baron, B., Groslambert, A., & Grappe, F. (2022). Using a Multidimensional Motivation's Scale during Effort to Understand How Motivation Evolves with Intensity and Fatigue. *Advances in Physical Education, 12,* 372-388.
https://doi.org/10.4236/ape.2022.124028

Received: October 10, 2022
Accepted: November 27, 2022
Published: November 30, 2022

Copyright © 2022 by author(s) and Scientific Research Publishing Inc.
This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).
http://creativecommons.org/licenses/by/4.0/
Open Access

Abstract

Motivation is an important factor in getting athletes to reach their maximal potential, but no questionnaire or scale to observe motivation *during* exercise has been developed. **Objective:** The first aim of this study was to test the validity and the reliability of a new French Multidimensional Motivation Scale during Effort (MMSE) constructed to determine Intrinsic Motivation (IM), External Regulation (ExtR), Introjected Regulation (IntroR), Identified Regulation (IdentR), Integrated Regulation (IntegR) and Amotivation (Am). The second aim was to use it during intermittent exercises to understand how motivation evolves with intensity and fatigue. **Methods:** A hundred and four trained athletes answered the French version of BREQ-3 and French MMSE before the protocol. Then, they performed a running test-retest (Test 1 and Test 2) around one loop (770 m) at level 4 of the CR10 Borg scale. Then, they were asked to perform five loops at the intensity of effort 2, 4, 6, 8 and 10 using the same scale (Test 3). Finally, 28 of these athletes were asked to perform more series of 20 squat jumps without charge until exhaustion (Test 4). **Results:** The results show that all motivational parameters of MMSE were correlated with BREQ-3, except for Am. No motivational parameter was significantly different between Test 1 and Test 2, and they were significantly correlated. During Test 3, IM was significantly reduced with intensity (−34.6%; $p < 0.001$) whereas the increase of IntegR (+17.3%; $p < 0.001$) helped to maintain a motivational reserve. During Test 4, the diminution of power output (−15.3%, $p < 0.05$) and the velocity (−19.1%, $p < 0.05$) were associated with an important decrease of IM (−81.2%, $p < 0.001$) and a slight decrease of IdentR (−37.3%, $p < 0.001$) and ExtR (−32.6%, $p < 0.05$). **Conclusion:** MMSE is valid and reliable to measure motivation during exercise. Autonomous parameters of motivation were the most evolving with the intensity of effort and fatigue.

Keywords

Motivation, Effort, Intensity, Fatigue

1. Introduction

Motivation is a psychological construct that moves people to act, think and develop (Deci & Ryan, 2008). In sports, high motivation is accepted as an important factor in getting athletes to reach their maximal potential, in particular, to pursue the effort despite the occurrence of fatigue (Baron et al., 2018). It can be defined as the force that energizes and directs behavior (Roberts & Treasure, 2012). Numerous scientific articles are about motivation (Buckworth et al., 2007; Gunnell et al., 2014). Typically, it was considered that the stronger the motivation, the greater the achievement and the more successful one's functioning (Bandura, 1996; Baumeister & Vohs, 2007). Conversely, Self-Determination Theory (SDT) claims that the quality of the motivation predicts specific outcomes, such as optimal and effective functioning, rather than the quantity of motivation (Ryan & Deci, 2017). SDT is one of the most popular approaches to motivation in sports (Deci & Ryan, 2013) and is considered as central in explaining motivation (Howard et al., 2017). It proposes a multidimensional concept of motivation which developed the idea that intrinsic and extrinsic reasons for behaving will lead to differential performance and well-being outcomes for individuals (Deci & Ryan, 2013). While intrinsic motivation refers to behaviors adopted for their own sake, extrinsic motivation is defined as doing something for an instrumental reason and can come in many forms. Howard et al. (2017) explained that motivated behavior can be divided into volitional (i.e. "I want to do this") and non-volitional action (i.e. "I have to do this") and that extrinsic motivation is divided into different forms varying in a locus of the degree of internalization.

Hence, different categories of behavioral regulations exist and lie on a continuum of self-determination (Ryan & Deci, 2017). From the most to the least self-determined, these categories are placed as follows:

Intrinsic Motivation (IM), Integrated Regulation (IntegR), Identified regulation (IdentR), Introjected Regulation (IntroR) and External Regulation (ExtR).

Intrinsic Motivation is characterized by the pleasure directly induced by the activity and by the interest in the practice. It refers to doing an activity for the pleasure and satisfaction derived from participation (Sheehan et al., 2018). Example in sports: This sport is pleasant.

The IntegR characterizes an athlete whose engagement in the activity is perceived as a part of his identity. It is when people perform an activity that is consistent with their values (Frielink et al., 2021). Example in sports: This sport represents values that are important to me and make me proud.

Identified regulation (IdentR): It corresponds to the behaviors seen as personally meaningful. People perform an activity because they value its importance and consider it to be beneficial for achieving their goals (Frielink et al., 2021). Example items, "I value the benefits of exercise" (Markland & Tobin, 2004). Example in sports: I think it's useful to become more efficient.

Introjected Regulation (IntroR): It represents internal pressure. Behavior is induced to achieve recognition or avoid personal feelings of guilt or shame, or enhance self-esteem.

Example in Sports: I would feel bad if I couldn't finish my training.

External Regulation (ExtR): Behavior is not choiceful but is influenced by psychological pressure. The athlete acts in order to obtain material or social reward from external sources such as a coach or parents. Example in sports: I feel compelled to do my training today.

Amotivation (Am): It corresponds to the lack of desire to engage in the behavior. Example in Sports: I can't find a reason to play tennis.

Different outcomes are induced by these distinct types of motivations (Frielink et al., 2021). Intrinsic motivation, integrated motivation and identified motivation, are often referred to as autonomous motivation and known to be more self-determined. They are associated with an increase in levels of physical activity (Levesque et al., 2007) and in life satisfaction and well-being (Ryan & Deci, 2017). Introjected motivation and external motivation are often referred to as controlled motivation and correspond to less self-determined types of motivation. They are known to be associated with negative outcomes such as depression (Levesque et al., 2007) psychological and physical ill-being (Ryan & Deci, 2017). Amotivation is associated with the most maladaptive outcomes (Ryan & Deci, 2000).

Studying motivation is of great importance, as it provides a theoretical and practical insight into why one initiates, regulates, sustains, directs and discontinues behavior (Clancy et al., 2017). Methodologically rigorous measurement is wanted to assess, apprehend, and predict the impact of any psychological construct on human behavior (Clancy et al., 2016). Self-document questionnaires are the most generally used dimension gear in motivation studies. Mainly, in sports psychology, there are a lot of motivation questionnaires (Clancy et al., 2016). Hence, Mayer et al. (2007) figured out over 75 questionnaires on motivation. Among these, the Behavioural Regulation in Exercise Questionnaire (BREQ) proposed by Mullan et al. (1997) was the first attempt to develop an instrument capable of tapping behavioral regulation according to SDT in the exercise domain (Cid et al., 2018). The BREQ assesses external, introjected and identified regulation, as well as intrinsic motivation, and several studies have provided support for its validity and reliability. Respondents reply to the question "Why do you engage in exercise?" on a scale ranging from 0 ("not true for me") to 4 ("very true for me") (Cavicchiolo et al., 2022). However, this first version didn't include the category of amotivation and a new revised version of the instrument was therefore developed (Cavicchiolo et al., 2022).

The BREQ-2 consists of 19 items, including four subscales for assessing the various forms of motivation (external, introjected, identified and intrinsic), with the addition of four items for measuring amotivation (Markland & Tobin, 2004). The BREQ-2 has become one of the most widely used instruments in the exercise domain and several studies conducted in different countries have provided support for its validity and reliability (Cid et al., 2012). Unfortunately, the BREQ-2 did not include integrated regulation, and yet another version of the instrument, the BREQ-3 was proposed (Wilson et al., 2006). The BREQ-3 includes the subscale of integrated regulation and contains 24 items, 4 for each subscale. The BREQ-3 is recognized to allow an understanding of the different motivational processes at work in the sphere of physical exercise (Wilson et al., 2006). This scale is translated into different languages, including French (Maillot et al., 2018).

Nevertheless, if valid and reliable measurement is a precursor to the understanding of any psychological construct (Clancy et al., 2017) to the best of our knowledge no questionnaire to observe motivation *during* exercise has been developed. Sheehan et al. (2018) explain that motivation is a complex construct, with athletes having diverse and dynamic motives for initiating, directing, sustaining, and terminating efforts. But in fact, all the publications in sports psychology deal with persistence in sports (Sarrazin et al., 2002), i.e. the perceived reasons for engaging or maintaining in an activity, rather than persistence during effort. In other words, what is usually studied is the reasons that push an athlete to return from one training session to another rather than the motivational mechanisms that allow him to continue a session or competition whereas fatigue occurs. This question is nevertheless of capital importance in high-level sports and is of interest to athletes and coaches. The last Ultra Trail of Mont Blanc (UTMB) is a good example of it. While Mathieu Blanchard and Kilian Jornet have been neck and neck for a long time, Kilian Jornet manages to detach in the last hectometers. The 2 athletes will all manage to pass under the mythical bar of 20h, beating the record of the event. Mathieu Blanchard says his motivation was decreased when Kilian Jornet left in front. But he also owes the fact of having beaten the record of the event to a sentence of a specter. He told him his time and the distance to the finish, telling him that he could finish in less than 20 hours. Mathieu Blanchard says that from that moment on he no longer felt any effort and that he had an impressive impression of ease (*Course Épique x UTMB 2022*: *L'UTMB de Mathieu Blanchard et Manon Bohard*, 2022).

Unfortunately, questionnaires that have been proposed to study the process of motivation by sports psychologists are too long and complex to be used during effort. For this reason, it is not yet known how motivation evolves during exercise. In literature about fatigue during exercise, the problem has been simplified by proposing to use the measure of the level of effort. Hence, based on motivational intensity theory (Brehm & Self, 1989; Wright, 2008), the psychobiological model of endurance performance (Marcora, 2008; Marcora & Staiano, 2010) proposes that the point at which people stop exercise is determined by the perception of effort, which is "the conscious sensation of how hard, heavy, and strenuous a physical task is" (Marcora, 2010) and potential motivation. Hence, the person consciously decides to stop exercising when the effort required by endurance exercise is perceived to exceed potential motivation, or when the perception of effort is so extreme that continuing the task seems impossible. Most of the time, the level of effort is determined using Likert's scale of Borg (1990) with only one question and thus is very frequently used in sports sciences because its determination is simple and fast.

On the one hand, motivation is recognized as a complex process with athletes having diverse and dynamic motives for initiating, directing, sustaining, and terminating efforts (Sheehan et al., 2018). Hence, the questionnaires allowing its evaluation before or after exercise include many items. On the other hand, the evaluation of motivation during exercise is based on a single parameter: the level of effort that can be sustained at a given moment. We claim that this single parameter alone cannot represent the complexity of motivational processes that determines not only the energisation but also the direction of behavior (Clancy et al., 2017; Roberts & Treasure, 2012). For this reason, there is no literature data about the evolution of the direction of motivation during exercise.

Therefore, the first aim of this study was to test the validity and the reliability of a new French Multidimensional Motivation Scale during Effort (MMSE) constructed to determine Intrinsic Motivation (IM), External Regulation (ExtR), Introjected Regulation (IntroR), Identified Regulation (IdentR), Integrated Regulation (IntegR) and Amotivation (Am). We hope to understand how motivation evolves with intensity and with fatigue and we hypothesize that the direction and intensity of motivation will change during the effort.

2. Methods

2.1. Participants

A hundred and four polyvalent athletes (27% females, 73% males, age: 20.30 ± 1.40 years; height: 1.76 ± 0.12 m; body mass: 66.78 ± 13.26 kg), students in sports sciences volunteered to take part in this experimental competition. They trained 12.2 ± 3.2 hours per week in different sports, including running and strength training.

All participants were accustomed to quantifying their individual perceived exertion (CR10) during 4 running sessions and other motivational parameters with the simplified multidimensional scale (MMSE).

Prior to participating in the event, each athlete provided written informed consent, and the study was conducted in accordance with the ethical principles of the Declaration of Helsinki (1984) and approved by the regional ethics committee.

All testing was performed in warm sunny weather at an altitude of 550 m with an average temperature of 25.5˚ and 70% of humidity.

2.2. Experimental Instrument

Validity of French Multidimensional Motivation Scale during Effort (*MMSE*):

Before exercises, athletes have to respond to the French version of the BREQ-3 (Maillot et al., 2018).

Respondents reply to the question "Why do you engage in exercise?" on a scale ranging from 0 ("not true for me") to 4 ("very true for me") (Cavicchiolo et al., 2022).

Then, Athletes were asked to respond to the French "Multidimensional Motivation's Scale during Effort" (MMSE) in order to compare the responses between BREQ-3 and MMSE.

The aim of the MMSE (**Figure 1**) is to determine the direction and the intensity of motivation for each category using a simplified questionnaire of the original. Thus, only one item was conserved for each motivational category and the scale questions the reasons for the continuation of the effort rather than the engagement in a sports activity. Hence, the sentence "Why do you engage in exercise?" was substituted by "why do you decide to continue your effort at this moment?".

For each question of the MMSE, the response was quantified between 1 to 7 rather than 0 to 4 in order to be more accurate.

1) Corresponds not all; 2) Corresponds a very little; 3) Corresponds a little; 4) Corresponds moderately; 5) Corresponds enough; 6) Corresponds a lot; 7) Corresponds exactly.

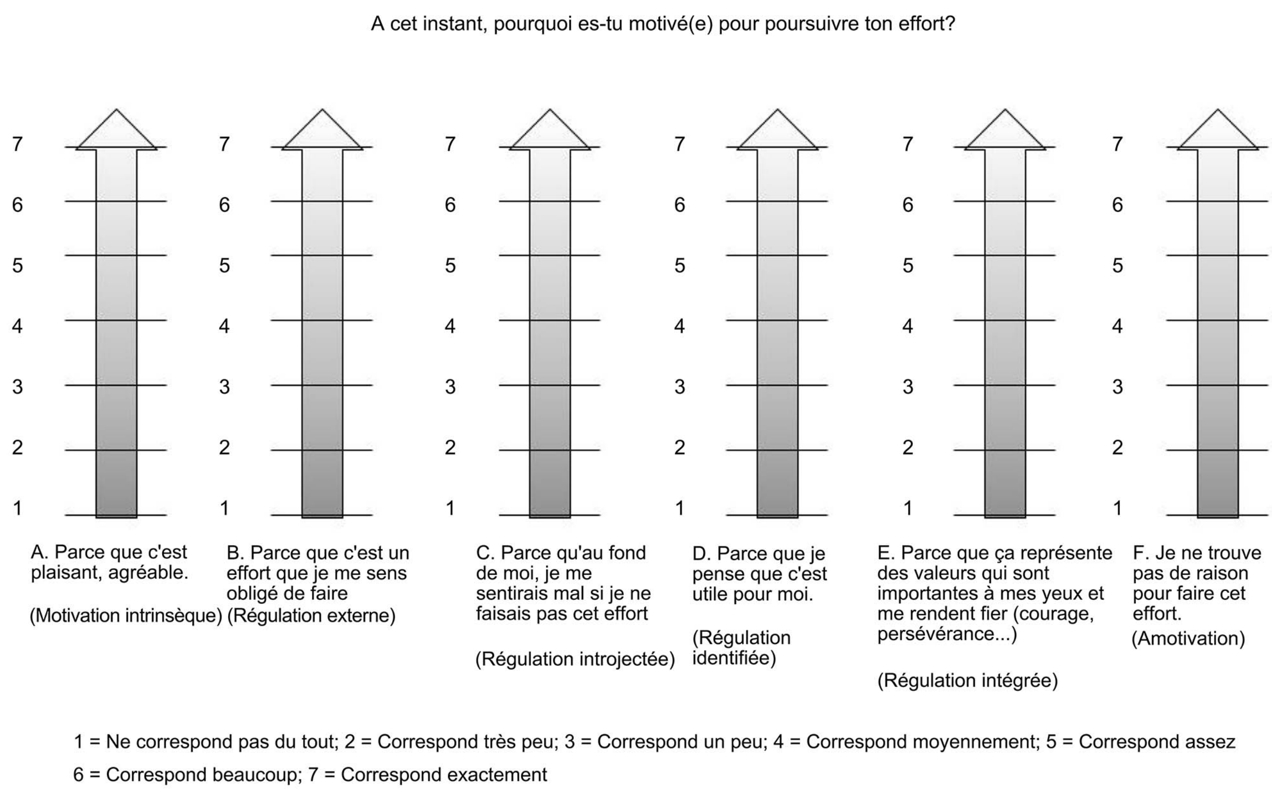

Figure 1. Presentation of the "Multidimensional Motivation's Scale during Effort" (MMSE).

In English, the question could be: "why do you decide to continue your effort at this moment?".

1) Because it's pleasant (intrinsic motivation).

2) Because I feel compelled to (external regulation).

3) Because I'll feel bad if I don't make the effort (Introjected regulation).

4) Because I think it is useful for me (identified regulation).

5) Because it represents values that are important to me and make me proud (integrated regulation).

6) I see no reason to make this effort (Amotivation).

Test 1 *and Test* 2: *Reliability test*

During these tests, the 104 athletes were asked to run once around one loop of 770 m with 12 m of elevation gain (D+) and 12 m of negative elevation gain (D−) at a "somewhat strong" intensity (intensity of effort 4) using the CR10 scale (Borg, 1990). The distance was chosen in order that fatigue remained low and did not interfere on the reliability.

The tests were performed one week apart and were used as test and retest in order to verify the reliability of the MMSE. At the end of each test, they respond to the MMSE.

In this study, the question was not asked during the exercise but during the short breaks between each repetition. This type of intermittent exercise is often used to administer perceptual questionnaires in sports sciences (Groslambert et al., 2020, 2021) and corresponds to the modality of many sports (team sports like handball or opposition sports like tennis). But answering the 6 questions takes less than 30 seconds and it would be possible to administer this scale during exercise during continuous activities such as running or cycling.

Test 3: *Influence of the intensity of effort*

The 104 athletes performed 5 loops of the same course as Test 1 and Test 2 (770 m, 12 m D+ and D−) at different intensities of effort (CR10). The distance was chosen in order that fatigue remained low. The aim was that results could principally depend on the intensity but few on the fatigue. The athletes were asked to run at intensity of effort 2, 4, 6, 8 and 10 of the CR10 scale (Borg, 1990) during the first, second, third, fourth and last loop, respectively.

At the end of each lap, the athletes had to stop for 5 min to respond to the MMSE and to drink and to recover enough from the fatigue of the previous round. The running time was measured using a manual digital chronometer and HR was continuously recorded (Garmin Forerunner ® 45, USA).

Test 4: *Influence of fatigue*

Two weeks later, twenty eight of the 104 athletes were volunteered to perform the more series of 20 squat jumps (until exhaustion) without charge (no additional external load) with 2 minutes break between each series. The athletes were encouraged to jump as high as possible with each repetition and to perform the most important number of series until exhaustion. The arms are free and can be used during the squat. A chair (46 cm) was placed behind the athletes. They had to descend until they were in contact with the chair before jumping.

Power, strength and velocity were measured with BEAST sensor, disposed on the ankle (Beast Technologies S.r.l. © 2014, Italy).

Between each series, the athletes had to stop only for 2 min in order that recovery was incomplete. MMSE and perceived exertion was measured using CR10 likert's scale (Borg, 1990) during this recovery period.

2.3. Statistical Analysis

Statistical analyses were made using JAMOVI (The JAMOVI project, 2021, Sydney, Australia).

Data are reported as the means ± standard deviations (SDs). As the results met the statistical assumptions for using parametric statistics (i.e. homogeneity of variance and normality of the sample distribution), a one-way Analysis of Variance (ANOVA) with repeated measures and Tukey post hoc test (JAMOVI) were performed to determine possible changes between laps in the velocity, HR and motivational parameters. Effect Sizes (ES) were calculated from extreme values using the formula of Hedges (1982). Cronbach's α was calculated between Test 1 and Test 2 to determine the internal consistency of MMSE.

The Pearson product-moment correlation coefficient was used to determine possible correlations between parameters. A p-value < 0.05 indicated that the difference was statistically significant.

3. Results

Validity of French Multidimensional Motivation Scale during Effort (*MMSE*):

Significant correlations were found between MMSE and BREQ-3 for IM ($p < 0.001$, r = 0.68), ExtR ($p < 0.05$, r = 0.37), IntroR ($p < 0.05$, r = 0.38), IdentR ($p < 0.005$, r = 0.45), IntegR ($p < 0.05$, r = 0.35), but not for Am ($p = 0.18$, r = 0.22).

Test 1 *and Test* 2: *Reliability test*

There is no significant difference between Test 1 and Test 2 (test-retest) for running velocity (10.0 ± 1.3 vs 10.0 ± 1.25 km·h^{-1}; $p = 0.48$), HR (128.82 ± 24.61 vs 128.89 ± 24.67 bpm; $p = 0.651$), intrinsic motivation (IM: 4.74 ± 1.90 vs 4.51 ± 1.35; $p = 0.25$; α = 0.73), external regulation (ExtR: 2.46 ± 1.88 vs 2.28 ± 1.72; $p = 0.22$; α = 0.73), introjected regulation (IntroR: 2.35 ± 1.51 vs 2.25 ± 1.45; $p = 0.57$; α = 0.87), identified regulation (IdentR: 4.77 ± 1.49 vs 4.82 ± 1.54; $p = 0.75$; α = 0.84), integrated regulation (IntegR: 4.23 ± 1.83 vs 4.39 ± 4.39 ± 1.72; $p = 0.29$; α = 0.79), amotivation (Am: 2.23 ± 1.50 vs 2.27 ± 1.48; $p = 0.55$; α = 0.80) and sum of motivational parameters (SumM: 18.55 ± 5.34 vs 18.23 ± 4.77; $p = 0.54$; α = 0.79).

Significant correlations were found between Test 1 and Test 2 (test-retest) for IM ($p < 0.001$, r = 0.53), ExtR ($p < 0.001$, r = 0.76), IntroR ($p < 0.001$, r = 0.50), IdentR ($p < 0.001$, r = 0.73), IntegR ($p < 0.001$, r = 0.76), Am ($p < 0.001$, r = 0.92) and SumM ($p < 0.001$, r = 0.64).

Test 3: *Influence of the intensity of effort*

Results of running velocity, HR and motivational parameters are presented in Table 1.

The running velocity and HR were highly correlated with CR10 ($p < 0.001$, r =

0.844 and $p < 0.001$, r = 0.742; respectively), HR was also highly correlated with running velocity ($p < 0.001$, r = 0.611).

IM was significantly correlated with the running velocity ($p < 0.001$, r = −0.220) and CR10 ($p < 0.001$, r = −0.279). Likewise, IntegR was significantly correlated with the running velocity ($p < 0.001$, r = 0.177) and the CR10 ($p < 0.001$, r = 0.165). Other motivational parameters were not significantly correlated with the running velocity nor with CR10 ($p > 0.05$).

Test 4: *Influence of fatigue*

Athletes performed 15.2 ± 9.1 series of 20 repetitions of squat jumps. In order to compare athletes that performed different numbers of series, results have to be expressed in percent of maximal number of series. For ANOVA and correlations, we examined results between 10%, 25%, 50%, 75% and 100% of the maximal number of series. The evolutions of biomechanical and motivational parameters are presented in **Table 2**.

The percentage of maximal series was correlated with average power ($p = 0.002$, r = −0.258), average velocity ($p < 0.001$, r = −0.303), CR10 ($p < 0.001$, r = 0.860), IM ($p < 0.001$, r = −0.752), ExtR (P= 0.003, r = −0.246), IntroR ($p = 0.010$, r = −0.218), IdentR ($p < 0.001$, r = −0.370) and with SumM ($p < 0.001$, r = −0.461). No significant correlation was found between the percentage of maximal number of series and average strength, IntegR and Am ($p > 0.05$).

The average power and the average strength were not correlated with any motivational parameter ($p > 0.05$). The average velocity was correlated with IM ($p = 0.041$, r = 0.173) and IdentR ($p = 0.040$, r = −0.174).

Table 1. Evolution of running velocity, HR and motivational parameters with intensity of effort.

Variables	Intensity of effort (CR10)							
	2	4	6	8	10	*P*-value and evolution (%) between intensity 2 and 10	*F*-value	Effect size
Running velocity (km·h^{-1})	7.86 ± 1.03	10.04 ± 1.26[a]	12.28 ± 1.72[a,b]	14.70 ± 2.37[a,b,c]	16.33 ± 1.25[a,b,c,d]	<0.001 + 107.7%	312	0.716
HR (bpm)	107.09 ± 24.17	128.82 ± 24.61[a]	145.58 ± 25.33[a,b]	167.18 ± 24.48[a,b,c]	179.70 ± 18.0 2[b,c,d]	<0.001 + 67.8%	169	0.554
IM	4.13 ± 2.17	4.20 ± 1.53	3.54 ± 1.71	3.12 ± 2.02 [b,c]	2.70 ± 2.10 [b,c,d]	<0.001 + 34.6%	11.8	0.084
ExtR	2.45 ± 1.83	2.46 ± 1.76	2.63 ± 1.81	2.60 ± 1.96	2.51 ± 2.01	0.943	0.19	0.001
IntroR	2.45 ± 1.69	2.29 ± 1.43	2.33 ± 1.48	2.72 ± 1.87	2.61 ± 1.98	0.318	1.18	0.009
IdentR	4.55 ± 1.79	4.70 ± 1.61	4.59 ± 1.86	4.62 ± 1.96	4.55 ± 2.16	0.976	0.118	0.001
IntegR	4.27 ± 2.01	4.03 ± 1.82	4.22 ± 1.84	4.87 ± 1.93 [b]	5.01 ± 2.20 [b,c]	<0.001 + 17.3%	5.02	0.038
Am	2.37 ± 1.67	2.34 ± 1.44	2.18 ± 1.40	2.26 ± 1.67	2.29 ± 1.83	0.936	0.204	0.002
SumM	17.85 ± 5.90	17.68 ± 5.03	17.26 ± 5.06	17.88 ± 5.75	17.35 ± 6.22	0.890	0.282	0.002

[a]: $p < 0.05$ compared with the precedent level of effort. [b]: $p < 0.05$ compared with the twice precedent level of effort. [c]: $p < 0.05$ compared with the third precedent level of effort. [d]: $p < 0.05$ compared with the fourth precedent level of effort. Intrinsic Motivation: IM, External Regulation: ExtR, Introjected Regulation: IntroR, Identified Regulation: IdentR, Integrated Regulation: IntegR, Amotivation: Am, and Sum of Motivation: SumM.

Table 2. Results of biomechanical (Power, strength, velocity), CR10 and motivational parameters during Test 4 (squat jumps) between 10% and 100% of maximal number of series.

Variables	percent of maximal series of squat							
	10%	25%	50%	75%	100%	*P*-value evolution between 25% and 100% (%)	*F*-value	Effect size
Power (watts)	991.09 ± 334.36	1026.12 ± 346.67	973.64 ± 378.65	826.56 ± 289.22	839.64 ± 260.34^{c}	0.028 − 15.3%	2.82	0.077
Strength (N)	925.62 ± 302.29	811.55 ± 277.62	819.55 ± 273.38	817.67 ± 258.30	839.64 ± 260.34	0.514	0.821	0.024
Velocity ($m \cdot s^{-1}$)	1.10 ± 0.25	1.12 ± 0.38	1.06 ± 0.23	0.98 ± 0.23	0.89 ± 0.18 ^{c,d}	0.007 − 19.1%	3.73	0.099
CR1O	2.24 ± 0.98	3.46 ± 1.05 ^{a}	6.38 ± 1.61 ^{a,b}	8.30 ± 1.25 ^{a,b,c}	9.15 ± 0.90 ^{b,c,d}	<0.001264.5%	56.8	0.763
IM	5.11 ± 1.62	3.96 ± 1.71	2.57 ± 1.29 ^{a,b}	1.64 ± 0.87 ^{c}	0.96 ± 0.69 ^{a,b,c,d}	<0.001 − 81.2%	47.4	0.584
ExtR	3.71 ± 1.58	3.79 ±1.52	3.07 ± 1.70	3.29 ± 1.94	2.50 ± 1.60 ^{c,d}	0.032 − 32.6%	2.73	0.075
IntroR	3.57 ± 1.89	3.39 ± 1.77	3.07 ± 1.92	2.79 ± 1.85	2.46 ± 1.69	0.158	1.68	0.047
IdentR	4.96 ± 1.43	4.46 ± 1.84	4.00 ± 1.59	3.50 ± 1.84	3.11 ± 1.69 ^{c,d}	<0.001 − 37.3%	5.43	0.139
IntegR	5.07 ± 2.16	4.96 ± 2.03	4.82 ± 1.81	4.64 ± 1.97 ^{c}	4.25 ± 1.86 ^{c,d}	0.558	0.752	0.022
Am	2.54 ± 1.20	2.64 ± 1.52	2.54 ± 1.37	2.36 ± 1.19	2.25 ± 1.11	0.794	0.420	0.012
SumM	22.57 ± 6.70	20.75 ± 6.44	17.75 ± 6.37 ^{b}	16.04 ± 6.46 ^{c}	13.57 ± 5.75 ^{c,d}	<0.001 − 39.9%	9.23	0.215

^{a}: $p < 0.05$ compared with the precedent percentage. ^{b}: $p < 0.05$ compared with the twice precedent percentage. ^{c}: $p < 0.05$ compared with the third precedent percentage. ^{d}: $p < 0.05$ compared with the fourth precedent percentage. Intrinsic Motivation: IM, External Regulation: ExtR, Introjected Regulation: IntroR, Identified Regulation: IdentR, Integrated Regulation: IntegR, Amotivation: Am, and Sum of Motivation: SumM.

CR10 was correlated with IM ($p < 0.001$, r = −0.692) but not with ExtR ($p = 0.156$, r = 0.200), IntroR ($p = 0.190$, r = 0.185), IdentR ($p = 0.160$, r = 0.198), IntegR ($p = 0.371$, r = −0.127), Am ($p = 0.546$, r = 0.086) and SumM ($p = 0.844$, r = 0.028).

To summarize, the results show that all motivational parameters of MMSE were correlated with BREQ-3, excepted for Am. No motivational parameter was significantly different between Test 1 and Test 2 and they were significantly correlated. During Test 3, IM was significantly reduced with intensity (−34.6%; $p < 0.001$) whereas the increase of IntegR (+17.3%; $p < 0.001$) helped to maintain a motivational reserve. During Test 4, the diminution of power output (−15.3%, $p < 0.05$) and the velocity (−19.1%, $p < 0.05$) were associated with an important decrease of IM (−81.2%, $p < 0.001$) and a slight decrease of IdentR (−37.3%, $p < 0.001$) and ExtR (−32.6%, $p < 0.05$).

4. Discussion

Whereas high motivation is accepted as an important factor in getting athletes to reach their maximal physical potential, measurements are so far realized only before or after exercise. In this study, we used a new scale that included one question for each category of motivation during exercise: Intrinsic Motivation, External

Regulation, Introjected Regulation, Identified Regulation, Integrated Regulation and Amotivation.

Significant correlations were found for each motivational category between MMSE and BREQ-3 before exercise, excepted for Am, suggesting that MMSE is valid to measure these categories. The reasons why Am is not correlated are unclear, perhaps the wording of the question may need to be revised.

Results of Test 1 and Test 2 (*Reliability test*) performed at a "somewhat strong" intensity of the CR10 (Borg, 1990) show that running velocity and HR were not significantly different and highly correlated, indicating that intensity and physiological responses are similar. The most important result of these tests is that there is no significant difference for IM, ExtrR, IntroR, IdentR, IntegR, Am and SumM between Test 1 and Test 2 (test and retest). Moreover, significant correlations were found for all these motivational parameters between test and retest.

This indicates the good test-retest reliability of MMSE and that it can be used during exercise.

Then, we used the MMSE during intermittent running exercise in which effort was progressively increased (Test 3). Results of ANOVA show that running velocity and HR increased with the intensity of effort (+107.7% and +67.8%, respectively). Moreover, running velocity was significantly correlated with CR10 whereas HR was significantly correlated with running velocity and HR as expected for this incremental test (Borg, 1990).

When the intensity of effort was progressively increased, results of ANOVA show that IM significantly decreased (−34.6%) while IntegR significantly increased (+17.3%). The other motivational parameters (ExtR, IntroR, IdentR, Am, and SumM) did not significantly evolve with intensity. Likewise, IM and IntegR were significantly correlated with intensity of effort and with running velocity whereas no correlation was found for the other parameters.

It is interesting to note that IM and IntegR are referred to as autonomous motivation and known to be more self-determined and that they are associated with an increase in levels of physical activity (Levesque et al., 2007). Let's remember that they are usually measured before or after activity and that our study is the first in which they are observed during effort. It seems that IntegR increased in levels of physical intensity in order to compensate for the decrease of IM. Thanks to that, SumM did not decrease even when maximal intensity was reached. The experimental design has been constructed in order that no important fatigue was induced during Test 3 to observe the effect of intensity but not fatigue. The HR values remain moderate (179.70 ± 18.02 bpm) for athletes of this age (20.30 ± 1.40 years), i.e. at only approximately 90% of theoretical maximal HR (Åstrand & Ryhming, 1954), suggesting that maximal physiological adaptations were not reached.

Our results suggest that when intensity was increased to maximal level of effort but without important fatigue, a motivational homeostasis could be maintained in parallel with physiological homeostasis.

Then, we wanted to check the evolution of the motivational parameters during a muscular exercise carried out until exhaustion (Test 4). ANOVA showed that the power significantly decreased until exhaustion (−15.3%). This confirms the occurrence of physiological fatigue (Edwards, 1983; Fitts, 1994). The decrease of power is in link with the diminution of velocity (−19.1%) whereas strength did not significantly change in accordance with previous studies (Thomasson & Comfort, 2012). In addition, the percentage of maximal number of series was significantly correlated with average power and average velocity but not with strength. Likewise, average power and average strength were not correlated with any motivational parameter whereas average velocity was significantly correlated with IM and IdentR.

This preponderant role of velocity in the decrease in power is also found in other studies. Indeed, Thomasson and Comfort (2012) found no significant reduction in force during the squat jumps performed at 60% 1 RM, but a significant reduction in velocity with a resultant significant decrease in power between the first and the last of the 6 repetitions that athletes have to realize.

In our study, an important reserve of power remained at the end of exercise (84.7%). It seems that the cessation of the exercise can be explained more by an abandonment than by a real physiological exhaustion as already shown for submaximal exercise (Baron et al., 2011). This hypothesis is in accordance with the evolution of motivational parameters.

Indeed, ANOVA shows a very important decrease of IM (−81.2%). IdentR slightly decreased with the percent of maximal number of series (−37.3%) whereas IntegrR did not significantly evolve, contrary to what we observed during Test 3 when intensity of effort has been increased until maximal without any important fatigue. Results revealed that ExtR also decreased (−32.6%) whereas IntroR, and Am did not significantly evolve. It is of interest to note that once again, as when intensity of effort was increased; autonomous motivation is most impacted by exercise. Indeed, IM, IntegR and IdentR are part of autonomous motivations and incorporate actions that athletes undertake volitionally (Sheehan et al., 2018). We already hypothesized that extrinsic motivational parameters have to compensate the decrease of IM during long to ultra-long endurance in order that effort could be maintained until the finish line (Baron et al., 2018).

But, when effort is maintained until exhaustion (Test 4), SumM decreased over the course of the test (−39.9%) contrary to what we observed during the test of increasing intensity of effort (Test 3). This time, with the onset of fatigue, it seems that no other motivational parameter could compensate for the very important decrease in IM.

Moreover, during Test 4, CR10 was correlated with no motivational parameter, except IM. This clearly shows that CR10 was not a good marker of motivation when an effort is maintained until exhaustion. This important result goes against the postulate that the CR10 represents the level of motivation (Brehm &

Self, 1989; Wright, 2008) but is in accordance with our hypothesis. However, the level of effort could be considered as the level of engagement necessary to compensate for the decrease in IM.

5. Conclusion

Until now, motivation could be measured among athletes outside of their physical activity, due to the lack of fast-enough tools. MMSE is a simplified scale based on a valid questionnaire that is used before or after exercise. MMSE seems to be valid and reliable to measure the continuum of motivational parameters during an effort with trained athletes. Our results show that IM seems sensitive to both the intensity of effort and fatigue. IntegR seems sensitive to effort whereas IdentR seems sensitive to fatigue.

When the intensity was progressively increased, IM significantly decreased whereas IntegR increased. This allowed that the SumM did not significantly evolve, testifying to the maintenance of motivational homeostasis.

When fatigue was induced by muscular exercise, IM highly decreased, whereas IdentR and ExtR slightly decreased. No compensatory mechanisms allowed SumM to remain stable.

It is of great interest that autonomous parameters, including IM, IntegR and IdentR, were the most evolving both when the intensity of effort was increased, and when fatigue occurs. IM, IntegR and IdentR are often referred to as autonomous motivation and are known to be more self-determined. In the studies that observe these parameters outside of the effort, they are known of important to initiating or maintaining a program of physical activity (Levesque et al., 2007) and are associated with well-being (Ryan & Deci, 2017). They incorporate actions that athletes undertake volitionally (Sheehan et al., 2018). When motivation is measured during effort, they seem to be the most mobilizable by athletes in order to respond to the increase in intensity and fatigue.

These results could provide interesting perspectives for coaches to better target the speeches during the competition and the effort towards the sense of effort and the values of the athletes.

Hence, the use of MMSE makes it possible to determine an individual motivational profile for the effort.

This study is the first to focus on the measurement and evolution of motivational parameters during an effort. Many studies are needed to confirm our results and to better understand the mechanisms that initiate, maintain or regulate motivation during effort in many different practice conditions. The use of the MMSE could open up an important field of investigation for sports performance but also for health. Of course, as with all new tools, it may need to be improved depending on the results of other experiments in other conditions and other populations. But even if it can be brought to be improved, it has the merit of finally allowing a measure of motivation during the effort.

Further studies are needed to test the sensitivity of the MMSE for other motivational parameters, in particular by varying the stakes (competitions, leisure, etc.), or by inducing satisfaction or disappointment. Indeed, Motivation results from the interaction of many diverse factors. For example, internal motives (e.g. needs for companionship) and/or external events (e.g. prize money) can move people to act (Mallett & Hanrahan, 2004). Moreover, further studies will be needed to test validity in English and other languages.

Acknowledgements

The authors would like to thank the students in sports sciences of Réunion Island who take part in this study.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Åstrand, P.-O., & Ryhming, I. (1954). A Nomogram for Calculation of Aerobic Capacity (Physical Fitness) from Pulse Rate during Sub-Maximal Work. *Journal of Applied Physiology, 7,* 218-221. https://doi.org/10.1152/jappl.1954.7.2.218

Bandura, A. (1996). Failures in Self-Regulation: Energy Depletion or Selective Disengagement? *Psychological Inquiry, 7,* 20-24. https://doi.org/10.1207/s15327965pli0701_3

Baron, B., Grappe, F., & Groslambert, A. (2018). The Global Model of Pacing Process for Long and Ultra-Long Distance. *Psychology, 9,* 2837-2850. https://doi.org/10.4236/psych.2018.914163

Baron, B., Moullan, F., Deruelle, F., & Noakes, T. D. (2011). The Role of Emotions on Pacing Strategies and Performance in Middle and Long Duration Sport Events. *British Journal of Sports Medicine, 45,* 511-517. https://doi.org/10.1136/bjsm.2009.059964

Baumeister, R. F., & Vohs, K. D. (2007). Self-Regulation, Ego Depletion, and Motivation. *Social and Personality Psychology Compass, 1,* 115-128. https://doi.org/10.1111/j.1751-9004.2007.00001.x

Borg, G. (1990). Psychophysical Scaling with Applications in Physical Work and the Perception of Exertion. *Scandinavian Journal of Work, Environment & Health, 16,* 55-58. https://doi.org/10.5271/sjweh.1815

Brehm, J. W., & Self, E. A. (1989). The Intensity of Motivation. *Annual Review of Psychology, 40,* 109-131. https://doi.org/10.1146/annurev.ps.40.020189.000545

Buckworth, J., Lee, R. E., Regan, G., Schneider, L. K., & DiClemente, C. C. (2007). Decomposing Intrinsic and Extrinsic Motivation for Exercise: Application to Stages of Motivational Readiness. *Psychology of Sport and Exercise, 8,* 441-461. https://doi.org/10.1016/j.psychsport.2006.06.007

Cavicchiolo, E., Sibilio, M., Lucidi, F., Cozzolino, M., Chirico, A., Girelli, L., & Alivernini, F. (2022). The Psychometric Properties of the Behavioural Regulation in Exercise Questionnaire (BREQ-3): Factorial Structure, Invariance and Validity in the Italian Context. *International Journal of Environmental Research and Public Health, 19,* Article 1937. https://doi.org/10.3390/ijerph19041937

Cid, L., Monteiro, D., Teixeira, D., Teques, P., Alves, S., Moutão, J., & Palmeira, A. (2018). The Behavioral Regulation in Exercise Questionnaire (BREQ-3) Portuguese-Version: Evidence of Reliability, Validity and Invariance across Gender. *Frontiers in Psychology, 9,* Article 1940. https://www.frontiersin.org/articles/10.3389/fpsyg.2018.01940 https://doi.org/10.3389/fpsyg.2018.01940

Cid, L., Moutão, J., Leitão, J., & Alves, J. (2012). Behavioral Regulation Assessment in Exercise: Exploring an Autonomous and Controlled Motivation Index. *The Spanish Journal of Psychology, 15,* 1520-1528. https://doi.org/10.5209/rev_SJOP.2012.v15.n3.39436

Clancy, R. B., Herring, M. P., & Campbell, M. J. (2017). Motivation Measures in Sport: A Critical Review and Bibliometric Analysis. *Frontiers in Psychology, 8,* Article 348. https://doi.org/10.3389/fpsyg.2017.00348

Clancy, R. B., Herring, M. P., MacIntyre, T. E., & Campbell, M. J. (2016). A Review of Competitive Sport Motivation Research. *Psychology of Sport and Exercise, 27,* 232-242. https://doi.org/10.1016/j.psychsport.2016.09.003

Course Épique x UTMB 2022: L'UTMB de Mathieu Blanchard et Manon Bohard (2022). https://www.youtube.com/watch?v=nQDnGz9WpIA

Deci, E. L., & Ryan, R. M. (2008). Facilitating Optimal Motivation and Psychological Well-Being across Life's Domains. *Canadian Psychology, 49,* 14-23. https://doi.org/10.1037/0708-5591.49.1.14

Deci, E. L., & Ryan, R. M. (2013). *Intrinsic Motivation and Self-Determination in Human Behavior*. Springer Science & Business Media.

Declaration of Helsinki (1984). *Déclaration d'Helsinki et révisions successive*. http://www.fondamentaux.org/?p=371

Edwards, R. (1983). *Biochemical Bases for Fatigue in Exercise Performance: Catastrophe Theory in Muscular Fatigue*. Human Kinetics Publishers.

Fitts, R. H. (1994). Cellular Mechanisms of Muscle Fatigue. *Physiological Reviews, 74,* 49-94. https://doi.org/10.1152/physrev.1994.74.1.49

Frielink, N., Schuengel, C., & Embregts, P. (2021). Evaluating the Self-Determination Continuum towards Seeking Support among People with Mild to Borderline Intellectual Disabilities. *Journal of Intellectual Disability Research, 65,* 348-360. https://doi.org/10.1111/jir.12819

Groslambert, A., Baron, B., Grappe, F., Scholler, V., Lacroix, E., & Ferreol, G. (2021). Tell Me How You Feel When You Run, I'll Tell You Who You Are. *Advances in Physical Education, 11,* 353-367. https://doi.org/10.4236/ape.2021.113030

Groslambert, A., Baron, B., Ouvrard, T., Desmoulins, L., Lacroix, E., Gimenez, P., & Grappe, F. (2020). Influencing Factors of Pacing Variations and Performance in a 44-Kilometer Mountain Trail Race. *Advances in Physical Education, 10,* 81-96. https://doi.org/10.4236/ape.2020.102008

Gunnell, K. E., Crocker, P. R., Mack, D. E., Wilson, P. M., & Zumbo, B. D. (2014). Goal Contents, Motivation, Psychological Need Satisfaction, Well-Being and Physical Activity: A Test of Self-Determination Theory over 6 Months. *Psychology of Sport and Exercise, 15,* 19-29. https://doi.org/10.1016/j.psychsport.2013.08.005

Hedges, L. V. (1982). Estimation of Effect Size from a Series of Independent Experiments. *Psychological Bulletin, 92,* 490-499. https://doi.org/10.1037/0033-2909.92.2.490

Howard, J. L., Gagné, M., & Bureau, J. S. (2017). Testing a Continuum Structure of Self-Determined Motivation: A Meta-Analysis. *Psychological Bulletin, 143,* 1346-1377. https://doi.org/10.1037/bul0000125

Levesque, C. S., Williams, G. C., Elliot, D., Pickering, M. A., Bodenhamer, B., & Finley, P. J. (2007). Validating the Theoretical Structure of the Treatment Self-Regulation Questionnaire (TSRQ) across Three Different Health Behaviors. *Health Education Research, 22,* 691-702. https://doi.org/10.1093/her/cyl148

Maillot, P., Becquard, C., & Perrot, A. (2018). Motivation des personnes âgées à pratiquer une activité physique. *Gerontologie et Societe, 40,* 127-142. https://doi.org/10.3917/gs1.156.0127

Mallett, C. J., & Hanrahan, S. J. (2004). Elite Athletes: Why does the "Fire" Burn So Brightly? *Psychology of Sport and Exercise, 5,* 183-200. https://doi.org/10.1016/S1469-0292(02)00043-2

Marcora, S. M. (2008). Do We Really Need a Central Governor to Explain Brain Regulation of Exercise Performance? *European Journal of Applied Physiology, 104,* 929-931. https://doi.org/10.1007/s00421-008-0818-3

Marcora, S. M. (2010). Effort: Perception of. In E. B. Goldstein (Ed.), *Encyclopedia of Perception* (pp. 380-383). Sage.

Marcora, S. M., & Staiano, W. (2010). The Limit to Exercise Tolerance in Humans: Mind over Muscle? *European Journal of Applied Physiology, 109,* 763-770. https://doi.org/10.1007/s00421-010-1418-6

Markland, D., & Tobin, V. (2004). A Modification to the Behavioural Regulation in Exercise Questionnaire to Include an Assessment of a Motivation. *Journal of Sport and Exercise Psychology, 26,* 191-196. https://doi.org/10.1123/jsep.26.2.191

Mayer, J. D., Faber, M. A., & Xu, X. (2007). Seventy-Five Years of Motivation Measures (1930-2005): A Descriptive Analysis. *Motivation and Emotion, 31,* 83-103. https://doi.org/10.1007/s11031-007-9060-2

Mullan, E., Markland, D., & Ingledew, D. K. (1997). A Graded Conceptualisation of Self-Determination in the Regulation of Exercise Behaviour: Development of a Measure Using Confirmatory Factor Analytic Procedures. *Personality and Individual Differences, 23,* 745-752. https://doi.org/10.1016/S0191-8869(97)00107-4

Roberts, G. C., & Treasure, D. (2012). *Advances in Motivation in Sport and Exercise*. Human Kinetics. https://doi.org/10.5040/9781492595182

Ryan, R. M., & Deci, E. L. (2000). Self-Determination Theory and the Facilitation of Intrinsic Motivation, Social Development, and Well-Being. *The American Psychologist, 55,* 68-78. https://doi.org/10.1037/0003-066X.55.1.68

Ryan, R. M., & Deci, E. L. (2017). *Self-Determination Theory: Basic Psychological Needs in Motivation, Development, and Wellness*. Guilford Publications. https://doi.org/10.1521/978.14625/28806

Sarrazin, P., Vallerand, R., Guillet, E., Pelletier, L., & Cury, F. (2002). Motivation and Dropout in Female Handballers: A 21-Month Prospective Study. *European Journal of Social Psychology, 32,* 395-418. https://doi.org/10.1002/ejsp.98

Sheehan, R. B., Herring, M. P., & Campbell, M. J. (2018). Associations between Motivation and Mental Health in Sport: A Test of the Hierarchical Model of Intrinsic and Extrinsic Motivation. *Frontiers in Psychology, 9,* Article 707. https://doi.org/10.3389/fpsyg.2018.00707

Thomasson, M. L., & Comfort, P. (2012). Occurrence of Fatigue during Sets of Static Squat Jumps Performed at a Variety of Loads. *Journal of Strength and Conditioning Research,* *26,* 667-683. https://doi.org/10.1519/JSC.0b013e31822a61b5

Wilson, P. M., Rodgers, W. M., Loitz, C. C., & Scime, G. (2006). "It's Who I Am … Really!" The Importance of Integrated Regulation in Exercise Contexts. *Journal of Applied Biobehavioral Research, 11,* 79-104. https://doi.org/10.1111/j.1751-9861.2006.tb00021.x

Wright, R. A. (2008). Refining the Prediction of Effort: Brehm's Distinction between Potential Motivation and Motivation Intensity. *Social and Personality Psychology Compass, 2,* 682-701. https://doi.org/10.1111/j.1751-9004.2008.00093.x