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# **Physiological and psychological factors to explain endurance performance in cycling**

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Physiological and psychological factors to explain endurance performance in cycling

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**Abstract**

Athletes, coaches and applied sport scientist assume that endurance performance is influenced by physiological *and* psychological factors. Therefore, the goal of the present study was to quantify what proportion of the variance in endurance performance in cycling is explained by psychological factors – in addition to the physiological variable  $\text{VO}_{2\text{max}}$ . Twenty-five young cycling athletes ( $15.3 \pm 0.5$  years) were examined in a cross-sectional study design.  $\text{VO}_{2\text{max}}$  ( $69.03 \pm 7.49 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ) was measured by a step incremental cycle ergometer test to exhaustion. Endurance performance ( $302.2 \pm 40.75 \text{ s}$ ) was measured as the required time in a time trial race on the mountain (1'320 m long, incline of 546 m). Psychological factors, namely self-talk, imagery, goal-setting, activation, relaxation, self-compassion, mental toughness, perseverance, level of ambition, action orientation, state orientation, were measured by using selectec questionnaires. A multiple regression model was created by using forward selection of regression model predictors. Results showed that  $\text{VO}_{2\text{max}}$  ( $B = -3.34$ ,  $\beta = .48$ ) and gender ( $B = 30.10$ ,  $\beta = .26$ ) were the best predictors for endurance performance and explained 74% of the variance in performance in mountain time trials. The psychological factor perseverance ( $\beta = .11$ ) and relaxation ( $\beta = .03$ ) explained an additional 14% of the variance. These findings suggest that physiological factors like  $\text{VO}_{2\text{max}}$  still are the best predictors for endurance performance. But psychological factors may help to explain more of the variance. For example, perseverance was associated with a better ( $B = -19.11$ ) and relaxation with a worse ( $B = 7.90$ ) endurance performance.

**Keywords:** endurance performance, psychological factors,  $\text{VO}_{2\text{max}}$ , cycling, perseverance, mental strategies

## Physiological and psychological factors to explain endurance performance in cycling

Endurance is generally understood as the athlete's psychophysical fatigue resistance. The psychological endurance includes the ability of the athlete to resist as long as possible to a stimulus that calls for the termination of load. The physical endurance includes the fatigue resistance of the entire organism or individual subsystems (Weineck, 2010). On the physiological level,  $\text{VO}_2\text{max}$  is one of the most important determinants. The  $\text{VO}_2\text{max}$  reflects the performance of the cardiovascular and the metabolic system and sets the upper limit for energy production in prolonged work. Therefore, a physiological factor like  $\text{VO}_2\text{max}$  can explain a large proportion ( $r \approx 0.8$ ) of the variance in endurance performance (McLaughlin et al., 2010), but not the entire variance.

In endurance sports, the thin line between winning and losing is becoming progressively thinner. When analyzing the development of the performance density in endurance sports, it was found that the differences at Olympic Games and World Championships have narrowed steadily in recent years. For example, in the period from 2011 to 2016, the difference between first and third place in male endurance events was only 0.4 percent (Wick, 2017). Athletes often use psychological factors to explain their performance. For example, an athlete might say that the race was won because of her ability to handle pressure and her enormous willpower. In other words, the athlete assumes that her performance is influenced by physiological *and* psychological factors. However, there are as yet no studies that investigate the simultaneous influence of physiological and psychological factors on endurance performance. In our study, we investigated whether psychological factors could explain variance in endurance performance beyond  $\text{VO}_2\text{max}$ .

The psychobiological model of endurance (Marcora, 2008) is an effort-based decision-making model based on motivational intensity theory, and explains how psychological factors influence endurance performance. The psychobiological model postulates that the conscious

regulation of pace is determined primarily by perception of effort and potential motivation. Perception of effort could be defined as “the conscious sensation of how hard, heavy and strenuous a physical task is” (Marcora, 2010, p. 380), and is considered the limiting factor of endurance performance. An increase in exercise tolerance therefore occurs either when potential motivation is increased or when perception of effort is reduced. Therefore, it is of great interest to athletes, coaches and applied sport scientists, to identify psychological factors which can, according to the theory of the psychobiological model, lead to an enhancement in endurance performance.

In the following sections, we will look at five psychological factors that may affect endurance performance, namely (1) use of mental strategies, (2) self-compassion, (3) mental toughness, (4) achievement motivation, as well as (5) action and state orientation.

A first factor is the use of mental strategies. Research has shown that successful athletes have more mental strategies to deal with exceptional situations than less successful athletes and use them more often (Moesch, 2008). The most used strategies to enhance athletic performance are self-talk, imagery, goal setting and arousal regulation (Vealey, 2007). The systematic use of self-talk (Van Raalte, Vincent & Brewer, 2016) is aimed to direct an athlete’s thoughts in a way that helps to increase motivation, to deal with anxiety, to strengthen confidence, to focus attention or to promote stress management. There is empirical evidence for the effectiveness of self-talk. For example, Blanchfield et al. (2014) showed that self-talk significantly reduces perceived perception of effort and increase time to exhaustion during high-intensity cycling exercise. The findings of Hatzigeorgiadis et al. (2017) also indicate that self-talk can have a positive impact on endurance cycling performance in hot conditions. Due to its simple implementation, competitive athletes frequently use imagery (Morris, Spittle & Watt, 2005). Research shown that imagery facilitates the delivery of athletic performance in various sports by influencing psychological states such as anxiety, self-confidence, self-efficacy, and attention (Jose & Joseph, 2018). Goal setting is a mental strategy to increase an individual’s commitment

toward achieving a personal goal (Weinberg & Butt, 2014). It can help to focus attention and it is critical to maintain and enhance motivation. Recent research has found support for the effectiveness of goal setting to enhance sport performance (Healy, Tinkchknell-Smith & Ntoumanis, 2018). Arousal regulations includes all techniques that influence physiological arousal by either decreasing or increasing it (i.e., activation or relaxation) (Acharya & Morris, 2014). Recent research has shown that there is positive correlation between sports performance and breathing techniques and other relaxation techniques (Parnabas et al., 2014). Therefore, it is assumed that athletes who can adapt their arousal have a greater chance to perform on a high level.

A second psychological factor that might influence endurance performance is self-compassion. Self-compassion is defined as the understanding, attentive and compassionate handling of personal mistakes, weaknesses and misfortunes, instead harshly criticizing oneself for experienced inadequacies (Neff, 2003). According to Neff (2003), self-compassion consists of three main components: self-kindness, common humanity, and mindfulness. Empirical data implies that self-compassion helps athletes dealing with adversities in sport. Self-compassion is related to less ruminative and less self-critical reactions to recent sport specific setbacks (Reis et al., 2015), more perseverance in athletes (Ferguson et al., 2015) and more constructive reactions to emotionally difficult sport situations (Ferguson et al., 2014). Therefore, self-compassion may be an important attribute for coping with challenges in sport such as performing in an endurance race.

A third psychological factor that can be considered relevant for endurance performance is mental toughness. Mental toughness is described as a set of positive attributes that allow an athlete to persevere through difficult situations (Gucciardi, 2017). Furthermore, mental toughness often associated with unshakeable self-belief, the ability to rebound after failures, persistence or refusal to quit, coping effectively with adversity and pressure, and retaining concentration in the face of many potential distractions (Liew et al., 2019). Research has shown

that better athletic performance is associated with higher mental toughness (Crust & Clough, 2005). Overall, most studies to date have shown that better athletes actually have higher toughness values (Gucciardi et al., 2009). Assumed that physical performance of top athletes is usually more homogeneous than their mental skills, mental toughness would be a potential factor that separates two athletes with the same skill and physical preparation.

A fourth psychological factor that might influence endurance performance is achievement motivation. Achievement motivation describes a need for success and a striving for excellence and includes perseverance (i.e., being persistent and investing a lot of energy in the accomplishment of athletic tasks) and a high level of ambition (i.e., preferring difficult tasks and setting demanding goals) (Frintrup & Schuler, 2007). Research findings support the existence of a positive relationship between achievement motivation and athletic performance (Zuber & Conzelmann, 2014).

A fifth psychological factor is action orientation and state orientation. Action orientation describes a quick refocusing after failure, and sometimes mistakes are even motivating. In contrast, state orientation describes a longer time to dwell when an error occurs (Beckmann, 2003). Accordingly, action-oriented athletes try to influence their mental, action-critical processes and concentrate on their actions. In contrast, state orientation refers to the inability to regulate these emotions, thought, and behaviors. State-oriented athletes tend to worry about the future and the past, instead than focusing on the actual demands during competitions. Previous research results indicate that state-oriented athletes have disadvantages compared to action-oriented athletes in various aspects that are relevant for athletic performance, particularly in stressful situations (Kröhler & Berti, 2019).

To our knowledge, there are no empirical data on the combined influence of  $\text{VO}_{2\text{max}}$  and psychological factors on endurance performance. Therefore, the goal of the present study is to quantify what proportion of the variance in endurance performance in cycling is explained by psychological factors – in addition to the physiological variable  $\text{VO}_{2\text{max}}$ . We hypothesized



that psychological factors (i.e., use of mental strategies, self-compassion, mental toughness, achievement motivation, action orientation and state orientation) explain a proportion of the variance in endurance performance in cycling – in addition to the physiological factor  $\text{VO}_{2\text{max}}$ .

## Methods

### Subjects and Procedure

A total of twenty-five subjects of the U17 Swiss Cycling national team voluntarily participated in the study. All subjects were performance-oriented cyclists and therefore accustomed to maximal cycling exercise.

**Table 1**  
Description of the study sample.

	age years	height cm	weight kg
female ( $n = 7$ )			
<i>M</i>	15.3	161.5	51.2
<i>SD</i>	0.7	3.9	3.9
male ( $n = 18$ )			
<i>M</i>	15.2	171.5	58.5
<i>SD</i>	0.4	7.2	9.9
<i>M</i>	15.3	168.7	56.5
<i>SD</i>	0.5	7.2	9.2

All participants and their parents provided written informed consent before participation in the study. The study was conducted in accordance with the Declaration of Helsinki and the Ethical Code of the Swiss Ethics Committees. The ethics application was approved by the Ticino Ethics Committee.

By using a medical questionnaire, we excluded health risks for the participants. The data collection took place over three days. On the first and second day, participants filled in a set of questionnaires to assess psychological factors and performed a  $\text{VO}_{2\text{max}}$  test. Data were recorded in a unique cross-section (observational, cross-sectional study design). On the third day, the participants completed a time trial on the mountain on a bicycle. We used a cross-

sectional study design with psychological factors and  $\text{VO}_2\text{max}$  as independent variables and duration in the mountain time trial (i.e., endurance performance) as the dependent variable.

## **Measures**

### **Physiological factors.**

Endurance performance was determined with a time trial race on the mountain in order to keep the effects of air resistance small. Endurance performance was defined as the time required for the race. The time trial race was 1'320 m long, with an incline of 546 m. After the test, lactate was measured, and the subjective perceived effort was documented by using Borg Ratings Scale. In our sample, mean lactate values of  $0.71 (\pm 0.24) \text{ mmol}\cdot\text{L}^{-1}$  and Borg values of  $17.76 (\pm 1.36)$  were measured.

$\text{VO}_2\text{max}$  was measured with a step incremental cycle ergometer test to exhaustion. The initial test workload was set at 100 W for women and 175 W for men for 60 s, after which power output was increased by  $25 \text{ W}\cdot\text{min}^{-1}$  until exhaustion. The participants were able to warm up on a bicycle ergometer before the test. To increase motivation, the athletes were shown on a monitor the time they had to reach in order to achieve the mean or best value of the next national team (U19). After the test, lactate was measured, and the subjective perceived effort was documented by using Borg Ratings Scale. In our sample, mean lactate values of  $0.98 (\pm 0.32) \text{ mmol}\cdot\text{L}^{-1}$  and mean Borg values of  $19.08 (\pm 0.76)$  were measured, which indicated that the athletes have exhausted themselves to the maximum.

### **Psychological factors.**

In order to assess mental strategies, participants were given a short description of five mental strategies (i.e., self-talk, imagery, goal-setting, activation and relaxation). These descriptions stem from the manual of the Test of Performance Strategies (TOPS). Subsequently, the athletes assessed each mental strategy as a single item and answered how often they used the particular strategy generally in a race (5-point Likert scale, never to always). An example item is: "I talk to myself in order to perform in competition."

Self-compassion was assessed using the total scale of the 12-item Self-Compassion Scale-Short Form (SCS-SF). Items were rated on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). The total SCS-SF score is obtained by reverse scoring the negative items and then computing the mean for all 12 items. In our sample, Cronbach's  $\alpha$  was .81 (95% CI .71-.91), while Hupfeld and Ruffieux (2011) reported a Cronbach  $\alpha$  of .91. An example item is: "When I'm going through a very hard time, I give myself the caring and tenderness I need."

Mental toughness was assessed using an informant-rated scale with 15 items (Hardy, Bell & Beattie, 2013). Items were rated on a 7-point Likert scale (1 = rarely, 7 = regularly). The total score was obtained by computing the mean for all 15 items. In our sample, Cronbach's  $\alpha$  was .89 (95% CI .83-.95), while Hardy et al. (2013) reported a Cronbach  $\alpha$  of .89. An example item is: "How much will your performance be affected, when the conditions are difficult?"

We assessed achievement motivation using the subscales "perseverance" and "level of ambition" of the SMT (Frintrup & Schuler, 2007). Items were rated on a 7-point Likert scale (1 = does not apply at all, 7 = fully applies). The scores for the subscales are obtained by reverse scoring the negative items and then computing the mean for all items. In our sample, Cronbach's  $\alpha$  was .53 (95% CI .22-.84) for perseverance and .62 (95% CI .38-.86) for level of ambition, while Frintrup & Schuler (2007) reported Cronbach  $\alpha$  of .83 for level of ambition and .73 for perseverance. An example item for perseverance is: "Despite setbacks and difficulties in training, I can always motivate myself." An example item for level of ambition is: "I particularly enjoy doing exercises that are very demanding in training."

Based on the subscale for action orientation after failure by Beckmann (2003), Horvath (2020) developed two 3-item scales to measure action orientation and state orientation. Items were rated on a 7-point Likert scale (1 = does not apply at all, 7 = fully applies). In our sample, Cronbach's  $\alpha$  was .77 (95% CI .61-.92) for action orientation and .32 (95% CI -.13-.78) for state orientation, while Horvath (2020) reported Cronbach  $\alpha$  of .52 for state orientation and .76 for action orientation. We slightly adapted the six items to fit the vocabulary in cycling (items

action orientation: “If I make a mistake in a downhill part of a race, I approach the next downhill part as if nothing had happened.”, “If I fail in an important situation in a race, I quickly forget about it and concentrate on the rest of the race.”, “If everything goes wrong in one day, then I continue to drive as determinedly as if it hadn't happened.”, items state orientation: “If I fail in an important situation in a race, then it goes through my mind repeatedly in the further course of the race.”, “If the coach criticizes my behavior, then it keeps me busy even during the race.”, “If I fail several actions in a row in a race, my thoughts circle around these failed actions for a long time.”).

### **Statistical analysis**

The statistical software R (version 3.6.3) was used for the data analysis. Mean values and standard deviations of all variables were calculated. T-test for comparison between male and female athletes was carried out for all psychological and physiological variables. For creating a multiple regression model with the dependent variable endurance performance, the physiological variable  $\text{VO}_2\text{max}$ , gender, all psychological factors as well as the interactions between  $\text{VO}_2\text{max}$  and all independent variables were considered as possible predictors. The final model was selected using the “leapForward” method of the “caret” R package (Kuhn, 2008). Briefly, this method performs “forward selection” of regression model predictors: it starts with no predictors in the model and iteratively adds the most contributive predictors. The best-performing number of predictor variables was then “tuned” (i.e. selected) using bootstrap-resampling (100 repetitions) of the dataset and subsequent calculation of the RMSE in observations not used for the fitting in the respective repetition of the bootstrap (“out-of-bag” observations). The number  $N$  of predictors with minimal average RMSE was chosen and the best combination of  $N$  predictor variables was used as the final model. Requirements for the application of regression analyses were checked using the usual methods.

## Results

Table 2 displays mean and standard deviations for the physiological variables endurance performance and VO<sub>2</sub>max and all psychological variables examined. Significant differences between men and women were found in endurance performance ( $p = .007$ ) and VO<sub>2</sub>max ( $p = .015$ ). No gender differences were found in all psychological factors ( $p > .125$ ).

**Table 2**  
Mean and standard deviations for all variables examined.

	female ( $n = 7$ )		male ( $n = 18$ )		overall ( $n = 25$ )	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
time trial (s)	344.43	39.64	285.78	27.75	302.2	40.75
VO <sub>2</sub> max (ml·kg <sup>-1</sup> ·min <sup>-1</sup> )	63.01	6.49	71.38	6.61	69.03	7.49
self-talk <sup>1</sup>	3.71	1.38	3.22	1.35	3.36	1.35
imagery <sup>1</sup>	4.14	0.90	3.94	0.73	4.00	0.76
goal-setting <sup>1</sup>	4.86	0.38	4.61	0.61	4.68	0.56
activation <sup>1</sup>	3.86	1.07	4.39	0.85	4.24	0.93
relaxation <sup>1</sup>	3.86	0.69	3.61	1.04	3.68	0.95
self-compassion <sup>1</sup>	3.67	0.70	3.53	0.46	3.57	0.52
mental toughness <sup>2</sup>	5.28	0.58	5.06	1.00	5.12	0.89
perseverance <sup>2</sup>	5.18	0.86	5.11	0.70	5.13	0.73
level of ambition <sup>2</sup>	5.66	0.57	5.54	0.88	5.58	0.79
action orientation <sup>2</sup>	5.43	0.99	5.07	1.40	5.17	1.29
state orientation <sup>2</sup>	2.81	0.74	3.43	1.10	3.25	1.03

Note. <sup>1</sup> = 5-point Likert scale, <sup>2</sup> = 7-point Likert scale

Table 3 displays the results of the regression analyses with the dependent variable endurance performance. The model ( $F(37.21, 4) = 20$ ) explained 86.0% of the variance in endurance performance. VO<sub>2</sub>max ( $B = -3.43$ ,  $\beta = .48$ ), gender ( $B = 30.10$ ,  $\beta = .26$ ) and the psychological factors perseverance ( $B = -19.11$ ,  $\beta = .11$ ) and relaxation ( $B = 7.90$ ,  $\beta = .03$ ) were the predictors for endurance performance in mountain time trials.

**Table 3**

Regression analysis for predicting endurance performance in mountain time trials.

	<i>B</i>	<i>SE B</i>	95% CI	$\beta$	<i>t</i>	<i>p</i>
VO <sub>2</sub> max	-3.34	0.49	[-4.37, -2.31]	.48	-6.76	< .001
gender	30.10	8.02	[13.36, 46.83]	.26	3.75	< .01
perseverance	-19.11	4.60	[-28.70, -9.52]	.11	-4.16	< .001
relaxation	7.90	3.54	[0.52, 15.28]	.03	2.23	.037

*Note.*  $R^2 = .88$ , Adjusted  $R^2 = .86$

## Discussion

The goal of the present study was to quantify what proportion of the variance in endurance performance in cycling can be explained by psychological factors – in addition to the physiological variable VO<sub>2</sub>max. Therefore, we examined a group of young cyclists and created a multiple regression model with the physiological factor VO<sub>2</sub>max, gender and selected psychological factors to predict endurance performance in mountain time trials. The results of our study showed that VO<sub>2</sub>max and gender were the best predictors for endurance performance. The psychological factors perseverance and relaxation accounted for an additional 14% of the variance in mountain time trials. In our sample, perseverance was associated with a better ( $B = -19.11$ ) and relaxation with a worse ( $B = 7.90$ ) endurance performance. Although many of the psychological factors examined did not influence endurance performance in our study, the hypothesis could be confirmed that certain psychological factors in addition to VO<sub>2</sub>max can explain part of the variance in endurance performance.

As expected, VO<sub>2</sub>max was the best predictor in our model to explain endurance performance in cycling. For both men and women, higher VO<sub>2</sub>max values reduced time in mountain time trials. We were therefore able to confirm that physiological characteristics like VO<sub>2</sub>max still are the most determining factors in endurance activities.

The second best predictor in our model was gender. As expected, male athletes achieved significantly better endurance performance than female athletes. Previous research with elite endurance athletes showed gender differences of approximately 12% in running, cycling, swimming and speed skating (e.g., Schumacher et al. 2001; Seiler et al. 2007). These gender

differences can generally be explained by lower body fat and higher  $\text{VO}_2\text{max}$  values in men. But also compared to the fat-free mass, the differences in  $\text{VO}_2\text{max}$  are still significant, which is probably due to higher levels of hemoglobin in men (Joyner, 1993). However, there are also examples of top male athletes with relatively low  $\text{VO}_2\text{max}$  values around  $70 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ , which female athletes occasionally exceed. Still, no woman could ever match their race times. Joyner (1993) therefore speculates that men with low  $\text{VO}_2\text{max}$  values have excellent running economy and lactate threshold values and thus faster competition times than female competitors with the same  $\text{VO}_2\text{max}$ . In our study, male and female athletes differed in their endurance performance and  $\text{VO}_2\text{max}$ . The gender differences in endurance performance also existed regardless of the higher  $\text{VO}_2\text{max}$  in men, which supports Joyner's speculation. No gender differences could be found in the psychological factors. It could therefore be assumed that psychological factors have only a small or even no influence on gender differences in endurance performance. Gender differences in endurance performance may be mainly influenced by physiological factors (e.g.,  $\text{VO}_2\text{max}$ , lactate threshold).

Perseverance was the best psychological factor in our model to explain endurance performance. The results of our study showed that higher perseverance resulted in better endurance performance. Perseverance is an important factor of an athletes achievement motivation and refers to the ability to being persistent and sticking to an athletic task despite obstacles, discouragement or adversity. Early research already showed that perseverance is strongly associated to high performance results, especially in endurance activities (Feltz, Short & Sullivan, 2008). Since peak performance depends on an excess of effort or the release of reserves (Beckmann & Kazén, 1994), it can be assumed that perseverance is a determining factor for high endurance performance. Athletes with high level of perseverance may be more able to perform on the upper limit of their physiological potential than less persistent athletes with similar physiological conditions. Regarding the psychobiological model, it could be speculated that perseverance could have a positive effect on both motivation and perception of

effort and therefore may enhance endurance performance by influencing the conscious regulation of pace.

The second psychological predictor in our model was relaxation, one of five mental strategies we examined. Compared to perseverance, relaxation could only explain a small proportion of the variance in endurance performance. Research has found that successful athletes use more relaxation techniques than less successful athletes (Gould, Eklund & Jackson, 1993) and that relaxation techniques can have a positive impact on performance (Parnabas et al., 2014). However, in our study, relaxation was associated with a worse endurance performance. An explanation for these findings could assume that too low arousal levels have a negative effect on endurance performance. It could be speculated that athletes who are too relaxed have difficulty in realizing their full physiological potential over a short race distance, where a cautious pacing strategy at the start of the race could have disadvantages. Another explanation for the negative impact of relaxation could be that weaker athletes are more likely to be nervous and therefore use more mental techniques such as relaxation. Nevertheless, a weakness of the present study is the use of a single item for the use of relaxation techniques, which did not refer to a specific technique. It would therefore be desirable for future research to use a more specific questionnaire to assess the conscious use of relaxation techniques. Furthermore, an extension of the measurement of endurance performance (e.g. long distance races) would also be interesting in order to investigate whether psychological factors have a higher or lower impact with longer race distances.

While many of recent research (e.g., McCormick, Meijen & Marcora, 2015) report positive effects of using mental strategies (e.g., self-talk, imagery, goal-setting, activation) on endurance performance, these factors were not suitable in our sample, to explain a portion of the variance in endurance performance. The current state of research could therefore not be proven. When comparing our results with previous findings, the question arises how efficiently the athletes in our sample can use mental strategies. It could be speculated that although the



athletes in our sample use mental strategies, the application is not yet efficient enough to have a positive impact on endurance performance. For example, many athletes may use self-talk, but only conscious use (e.g., motivational self-talk) may improve performance. Since mental strategies are learnable skills, it would be interesting to investigate junior athletes differ from experienced elite athletes regarding the influence of mental strategies on endurance performance.

In the area of practical application, the findings of the present study could be used to systematically influence the psychological factors examined for enhancing endurance performance. In addition, psychological factors may also be suitable for talent screening in endurance sports.

As far as we know, this was the first study on the common influence of physiological and psychological variables on endurance performance. The results of this study suggest that physiological factors like  $\text{VO}_2\text{max}$  are still the best predictors for endurance performance, but psychological factors may explain an additional part of the variance too. These findings may lead to a better understanding of the common influence of physiological and psychological factors and could be used as a basis for further research. Future research could therefore examine additional psychological factors to identify other suitable predictors of endurance performance, in addition to physiological factors. It could also be examined whether the results of our study with young cyclists can also be transferred to other endurance sports. Furthermore, it would also be desirable to conduct a meta-analysis of our question in the near future. Our investigation of a small sample should be able to contribute to this.

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### Declaration of interest statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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## **Eigenständigkeits- und Urheberrechtserklärung**

Ich versichere, dass ich die Arbeit selbstständig und ohne unerlaubte fremde Hilfe angefertigt habe. Alle Stellen, die ich wörtlich oder sinngemäss Veröffentlichungen oder anderweitig fremden Quellen entnommen habe, sind gemäss den Zitations-Regeln der Eidgenössischen Hochschule für Sport Magglingen als solche gekennzeichnet.



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Marco Wyler

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