University of Groningen

Psychomotor speed is related to perceived performance in rowers

Nederhof, Esther; Visscher, Chris; Lemmink, Koen

Published in:
European Journal of Sport Science

DOI:
[10.1080/17461390802195678](https://doi.org/10.1080/17461390802195678)

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Early version, also known as pre-print

Publication date:
2008

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Nederhof, E., Visscher, C., & Lemmink, K. (2008). Psychomotor speed is related to perceived performance in rowers. *European Journal of Sport Science*, 8(5), 259-265. <https://doi.org/10.1080/17461390802195678>

Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

This article was downloaded by: [University of Groningen]

On: 17 January 2012, At: 02:40

Publisher: Taylor & Francis

Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK

European Journal of Sport Science

Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/tejs20>

Psychomotor speed is related to perceived performance in rowers

Esther Nederhof^a, Chris Visscher^a & Koen Lemmink^b

^a Center for Human Movement Sciences and University Center for Sport, Exercise and Health, University Medical Center Groningen, University of Groningen, Netherlands

^b School of Sports Studies, Hanze University of Applied Sciences, Groningen, Netherlands

Available online: 03 Oct 2008

To cite this article: Esther Nederhof, Chris Visscher & Koen Lemmink (2008): Psychomotor speed is related to perceived performance in rowers, European Journal of Sport Science, 8:5, 259-265

To link to this article: <http://dx.doi.org/10.1080/17461390802195678>

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: <http://www.tandfonline.com/page/terms-and-conditions>

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae, and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand, or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

ORIGINAL ARTICLE

Psychomotor speed is related to perceived performance in rowers

ESTHER NEDERHOF¹, CHRIS VISSCHER¹, & KOEN LEMMINK²

¹Center for Human Movement Sciences and University Center for Sport, Exercise and Health, University Medical Center Groningen, University of Groningen, Netherlands, and ²School of Sports Studies, Hanze University of Applied Sciences, Groningen, Netherlands

Abstract

The goal of the present study was to determine if psychomotor speed is related to perceived performance. It was hypothesized that lower perceived performance was related to longer reaction times. A total of 85 measurements were taken in 26 varsity rowers (mean age 21.3 years, $s = 1.6$) on five occasions over the course of the season. Perceived performance was measured with the “Reduced Sense of Accomplishment” scale of the Athlete Burnout Questionnaire. Reaction times were measured with the finger pre-cueing task and with the action and reaction modes of the determination test. The complex structured data were analysed with multi-level modelling. Random intercept linear models showed that perceived performance was not related to reaction times on the finger pre-cueing task. Perceived performance significantly predicted reaction times on the action and reaction modes of the determination test. In rowers who were not selected for the team after completing two measurement sessions, this relationship did not exist in the action mode; deselection was a moderator. Thus, a significant relationship between reaction times on the determination test and perceived performance was observed. It was concluded that the determination test could be a useful tool to monitor rowers’ responses to training, although several issues should be resolved before it can be used in practice.

Keywords: *Overtraining, overreaching, hierarchical linear model*

Introduction

Many training hours are required to reach the top in sports. Athletes are usually afraid of training too little. However, too much training can also result in performance decrements and fatigue. The consequences of excessive training can be classified into three groups: functional overreaching, non-functional overreaching, and overtraining syndrome (Meeusen *et al.*, 2006; Nederhof, Lemmink, Visscher, Meeusen, & Mulder, 2006). In the latter two cases, withdrawal from practice and competition is necessary (Meeusen *et al.*, 2006; Uusitalo, 2001). Prevention of non-functional overreaching and overtraining syndrome therefore seem the best solution. A large number of studies have been devoted to the early detection of non-functional overreaching and overtraining syndrome (for extensive reviews, see Halson & Jeukendrup, 2004; Meeusen *et al.*, 2006; Urhausen & Kindermann,

2002). However, these efforts have not led to a reliable, applicable marker.

It has recently been suggested that psychomotor speed might be a marker for non-functional overreaching and overtraining syndrome (Nederhof *et al.*, 2006). Psychomotor speed can be assessed through computerized reaction time tasks. The advantage of this method is that it is easy to apply in training practice. A standardized computer set up in a quiet room is all that is needed.

Apart from high face validity, some support for the psychomotor slowness hypothesis has been found. The first to support this hypothesis were Rietjens and colleagues (2005). They measured the reaction times of seven cyclists before and after a 2-week period of increased training. The cyclists increased their training load by 107%. Compared with controls, who did not increase their training load, the reaction times of the cyclists were longer on the most difficult conditions of the task (Rietjens *et al.*, 2005).

Correspondence: E. Nederhof, Centre for Human Movement Sciences, University of Groningen Medical Centre, PO Box 196, 9700 AD Groningen, Netherlands. E-mail: e.nederhof@med.umcg.nl

Comparable results were reported by Nederhof and colleagues (Nederhof, Lemmink, Zwerver, & Mulder, 2007). They also measured reaction times in cyclists before and after a period of high load training. In their study, the training load was increased by 100%, which resulted in five functional overreached cyclists. Those cyclists showed longer reaction times compared with a control group who did not increase their training loads (Nederhof *et al.*, 2007). Whereas Nederhof *et al.* (2007) showed both performance decrements and changes in mood states, Rietjens *et al.* (2005) only showed changed mood states. The athletes who participated in the latter study did not show performance decrements after high load training (Rietjens *et al.*, 2005).

The question arises as to whether psychomotor speed is sensitive to changes in performance or to changes in perceived performance. If it were the case that psychomotor speed changes in the early stages of overreaching, when performance decrements are not yet present, it would be a good marker. The advantage of measures of psychomotor speed is their objectivity, as opposed to subjective questionnaires. This practical applicability gives psychomotor speed an advantage over clinical markers, such as hormone concentrations or immunological parameters. The purpose of the present study was to determine whether psychomotor speed is sensitive to changes in perceived performance in a normal rowing season. The hypothesis was that decrements in perceived performance would be related to longer reaction times.

Methods

Participants

The participants in the present study were 26 Dutch varsity rowers (14 males, 12 females), all of whom

rowed in national competitions. Their mean age at the beginning of the study was 21.3 years ($s = 1.6$). They started rowing at the age of 18.5 years ($s = 2.0$) and had been rowing in national competitions for 1.7 years ($s = 1.0$) on average. The participants practised 6.6 times ($s = 1.2$) a week, averaging 11.2 h ($s = 2.2$) per week. They participated on average in 18.5 racing days ($s = 2.0$) a year. All participants signed informed consent. The procedures of the study were in accordance with ethical standards of the Helsinki Declaration. The Medical Ethics Committee of the University Medical Centre Groningen approved the study procedures.

Instruments

Finger pre-cueing task. The finger pre-cueing task is a four-choice reaction time task in which a cue reduces the amount of possible stimulus/response locations to two in three out of four conditions (Adam, Hommel, & Umiltà, 2003; Miller, 1982) (see Figure 1). The cue signal consisted of two plus signs either below the two leftmost or the two rightmost plus signs (hand-cued condition), below the middle or outer two plus signs (finger-cued condition), or below the rightmost and left of the middle or below the leftmost and right of the middle plus signs (neither-cued condition), or the cue signal consisted of four plus signs below the warning signal (uncued condition). After a time interval of 500 ms, the target signal appeared below the cue row always in a position indicated by the cue. The participants' task was to respond as quickly as possible to the target signal by pressing the appropriate key. Each test session consisted of 160 trials, always preceded by 10 practice trials.

Mean reaction time was calculated for each participant for each pre-cueing condition. Incorrect responses as well as reaction times shorter than 150 ms

Figure 1. Schematic overview of the finger pre-cueing task. The warning signal (upper row) appeared 1000 ms before the cue (middle row). The target stimulus (lower row) appeared 500 ms after the cue. The target always appeared in one of the positions indicated by the cue, allowing the participants to selectively prepare stimulus detection and response execution in the three cued conditions.

or longer than 1000 ms were omitted in the calculation of mean reaction time. Information on the reliability of the finger pre-cueing task is not available at the present time. However, reliability is assumed to be high, as small differences between conditions can be detected in within-participant designs (Adam & Moresi, 2007).

Determination test. The determination test, performed on the Vienna Test System (Schuhfried, Moedling, Austria), is a reaction time test with five different visual stimuli to which a manual reaction is required, two visual stimuli to which a pedal reaction is required, and one auditory stimulus to which a manual reaction is required (Figure 2). In the action mode, a new stimulus occurs as soon as a correct reaction is given. In the reaction mode, the stimuli occur in six blocks with pre-set presentation times of 1.225, 0.948, 0.834, 0.734, 0.646, and 0.834 s, and two visual stimuli that require manual reactions in the action mode should be inhibited. Both the action and the reaction mode were always preceded by a computerized instruction including a practice session.

Figure 2. Picture of the test equipment used for the Vienna determination test. The participants had to respond manually to coloured circles that appeared on the screen by pressing the coloured buttons at the upper centre of the response board. The participants had to respond to a sound by pressing the black bar at the centre of the board and to two grey rectangles that appeared at the lower left or right side of the screen by pressing the foot pedals with the left or right foot, respectively.

Median reaction times were calculated for the action mode and for the six subsequent presentation intervals of the reaction mode separately only for correct, on-time responses. The determination test has high reliability, with Cronbach's alpha and split-half reliabilities mostly above 0.9 and of at least 0.8 (Neuwirth & Benesch, 2003).

Perceived performance. Perceived performance was assessed with the "Reduced Sense of Accomplishment" scale of the Athlete Burnout Questionnaire (Raedeke & Smith, 2001). The scale consists of five items about feelings of success, achievement of goals, and performance. Questions are answered on a 5-point Likert scale anchored by 1 = "almost never" and 5 = "almost always". Scores were calculated by adding item scores and dividing the total by five. The higher the score, the lower was their perceived performance. The Athlete Burnout Questionnaire has sufficient reliability and validity (Raedeke & Smith, 2001).

Procedure

The participants came to the laboratory on up to five occasions during the rowing season, which lasts from September to July. They arrived at the laboratory at the same time of day on each measurement occasion. The participants were asked to keep their diet and activity prior to testing constant between sessions. Upon arrival at the laboratory, the participants first performed one of the reaction time tasks. They then completed the Athlete Burnout Questionnaire, after which they performed the second reaction time task. The order of the reaction time tasks was counter-balanced between participants, but was kept constant within participants.

Data analysis

The complex structured data were analysed using the multi-level modelling program MLwiN (Goldstein *et al.*, 1998). Multi-level modelling is an extension of multiple regression and was developed for analysing hierarchically structured (or nested) data, where the hierarchy defines several levels. Three different models were calculated: one model with reaction times on the finger pre-cueing task, one with reaction times in the action mode of the determination task, and one with the reaction mode of the determination task. In all three models, the participants represented the highest level. Measurement occasions were nested in participants. In the case of the finger pre-cueing task, the four conditions (nested within each measurement occasion) formed the lowest level (level 1) units. The six blocks of the reaction mode of the determination task also repre-

sented the lowest level. In the case of the action mode of the determination task, the measurement occasions were the lowest level units, as this part of the determination task does not have conditions or blocks.

Multi-level modelling is preferable to traditional methods because it takes into account the variation at the different levels in addition to the mean group response. Another advantage is that a different number of measurements per participant is allowed, as was the case in the present study. As a number of participants dropped out from the study for different reasons, the assumption that data were missing at random did not hold. This problem was accounted for by using the reason for drop-out as a predictor in the model.

Reaction times were modelled using a random intercept model in which all parameters had a fixed effect, except the constant or intercept, which varied randomly over all levels. From the baseline model, in which a satisfactory modelling of reaction times over time (and conditions/blocks) was sought by specifying an adequate variance structure as simple as possible, additional variables were added. First, information about the reason for drop-out and gender were entered. Second, perceived performance and interactions with measurement occasions, reason for missing data, and conditions or blocks were entered. A variable significantly contributed to the model if the z -score reached the critical value of $P < 0.05$ (Snijders & Bosker, 1999, p. 86). The z -scores were calculated by dividing the estimate by its standard error.

Results

In total, 85 data sets were obtained among 26 rowers. During the season, 10 rowers (5 males, 5 females) withdrew from the study because they were not selected for the team. Deselection took place just before the third measurement occasion for nine rowers. Another four female rowers withdrew from the study after the third measurement occasion because they perceived participation as too demanding. All other missing data points were random or for reasons that were too infrequent to group.

A piecewise linear model with random intercept adequately represented the development of the four finger pre-cueing task conditions over time (Table I). Reaction times at the second measurement occasion were used as the reference. Reaction times at the first occasion were modelled relative to the second. Reaction times at the third, fourth, and fifth occasion were also modelled together relative to the second occasion. Reaction times at the first measurement occasion were significantly longer than at the second measurement occasion. Reaction times at

Table I. Multi-level regression model for reaction times (ms) on the finger pre-cueing task

Parameter	Estimate	Standard error
Fixed		
intercept	375.5	16.8
occasion 1	35.3	6.9
occasions 3, 4, 5	-4.8	7.1
hand cued	-54.3	2.9
finger cued	-31.5	2.9
neither cued	-16.7	2.9
deselected	4.9	16.1
withdrawal	68.4	21.2
perceived performance	-1.5	5.4
Random		
Level 3 (between rower)	1147.7	377.7
Level 2 (between occasion, within rower)	504.1	110.6
Level 1 (between condition, within occasion)	341.2	30.6
Deviance		
-2 * log-likelihood	3089.2	

the later measurement occasions did not differ from reaction times at the second measurement occasion.

Reaction times on the hand cued, finger cued, and the neither cued conditions were significantly shorter than on the uncued condition. Reason for drop out, withdrawal or deselection was modelled relative to reaction times of rowers who had no (reason for) missing data. The reaction times of the four female rowers who withdrew from the study were significantly longer, whereas those of the deselected rowers did not differ significantly from the reaction times of the other rowers. As reaction times are usually not different between males and females and gender did not contribute to the model *over the effect of reason for drop out*, it was not included in the final model. No main effect of perceived performance was observed.

Interaction effects of perceived performance with measurement occasion and reason for drop out were not significant. Perceived performance did not show interaction effects with finger pre-cueing task conditions, except for the neither cued condition. For every extra point on the "Reduced Sense of Accomplishment" scale, the participants were 6 ms faster on the neither cued condition. We did not present these results in the final model, because the model as a whole did not improve significantly (i.e. the deviance, which is a measure of model fit, was tested against the χ^2 distribution with three degrees of freedom, because three factors were added: $\chi^2 = 6.043$, $P > 0.05$) and the absolute difference was very small (Table I).

Reaction times for the action mode of the determination test were best represented in a random intercept model with estimates for every measurement occasion (Table II). Reaction times at the first measurement occasion were used as reference in the

Table II. Multi-level regression model for reaction times (ms) on the action mode of the determination test

Parameter	Estimate	Standard error
Fixed		
intercept	735.4	16.7
occasion 2	-69.4	5.8
occasion 3	-97.0	6.5
occasion 4	-120.2	8.3
occasion 5	-134.9	9.7
deselected	18.6	28.6
withdrawal	42.7	58.1
perceived performance	18.3	5.2
perceived performance * deselected	-24.4	10.4
perceived performance * withdrawal	-10.3	27.4
Random		
Level 2 (between rower)	1222.8	375.6
Level 1 (between occasion, within rower)	380.1	70.6
Deviance		
-2 * log-likelihood	799.3	

model. Reaction times at the other measurement occasions were modelled relative to the first and all differed significantly from the first occasion. Reaction times of the deselected rowers and of the four female rowers who withdrew from the study did not differ from the other rowers. Perceived performance significantly predicted reaction times. In other words, for every extra point a rower scored higher on the “Reduced Sense of Accomplishment” scale, reaction time increased by 18 ms.

A significant interaction effect of reason for drop out was observed. The fact that some rowers were not selected for the team moderated the relation between perceived performance and reaction time. The reaction times of these rowers were 6 ms shorter (i.e. 18 – 24) for every point they scored higher on the “Reduced Sense of Accomplishment” scale (Figure 3). The other interaction effects were not significant.

Reaction times for the reaction mode of the determination test were also best represented by a random intercept model with estimates for every measurement occasion (Table III). Again, reaction times at all measurement occasions differed significantly from the first. The reaction times of blocks 2–6 were significantly faster than those of the first block, which was used as the reference block. In this model, the reaction times of deselected rowers and the rowers who withdrew from the study did not differ significantly from those of the other rowers. Perceived performance significantly predicted reaction times.

Interaction effects were not significant, except the interaction between perceived performance and the second measurement occasion. This interaction showed that the existing relation between perceived

Figure 3. Model estimates of reaction times on the determination test for every measurement occasion (m1, m2, m3, m4, and m5) for rowers without (a reason for) missing data and for the deselected rowers (m1d and m2d). The length of the lines represents the range of scores at the different measurement occasions in the two groups. This figure shows the moderating effect of deselection. Lines m1–m5 show a positive slope, while lines m1d and m2d show a slightly negative slope.

performance and reaction time was not present at the second measurement occasion. Because the model with the interaction had a worse fit (i.e. a higher deviance) and the interaction was not interpretable, the interaction was not presented in the final model (Table III).

Discussion

The hypothesis that decrements in perceived performance would be related to longer reaction times was supported by the results of the determination test but not those of the finger pre-cueing task. The

Table III. Multi-level regression model for reaction times (ms) on the reaction mode of the determination test

Parameter	Estimate	Standard error
Fixed		
intercept	694.2	16.8
occasion 2	-49.0	5.8
occasion 3	-71.6	6.8
occasion 4	-80.1	8.4
occasion 5	-96.8	10.2
block 2	-32.1	5.7
block 3	-32.8	5.7
block 4	-43.6	5.7
block 5	-52.6	5.7
block 6	-51.4	5.7
deselected	-28.1	18.1
withdrawal	33.0	24.0
perceived performance	12.3	4.2
Random		
Level 3 (between rower)	1582.7	482.8
Level 2 (between occasion, within rower)	193.5	79.5
Level 1 (between block, within occasion)	1384.9	95.0
Deviance		
-2 * log-likelihood	5253.7	

multi-level models (Tables II and III) showed that rowers who scored higher on the “Reduced Sense of Accomplishment” scale of the Athlete Burnout Questionnaire had longer reaction times on the determination test. For every point the rowers scored higher, their reaction times were 18 ms longer on the action mode and 12 ms on the reaction mode of the determination test. This effect was not found for the finger pre-cueing task.

On both reaction time tasks, an effect of measurement occasion was found. On the finger pre-cueing task, reaction times became shorter from the first to the second measurement occasion. Thereafter, reaction times did not change. On the determination test, reaction times became shorter every measurement occasion. Thus, practice effects were different for the two reaction time tasks. Further research is required to determine what happens with reaction times on following measurement occasions before the determination test can be used in practice.

On the finger pre-cueing task, a significant effect of condition was found. The uncued condition resulted in the longest reaction times, followed by the neither cued condition, the finger cued condition, and the hand cued condition. This pattern reflects the advantage of the pre-cue information over the four-choice, uncued condition, an effect that is usually present (Adam *et al.*, 2003; Miller, 1982). In the reaction mode of the determination test, a significant effect of block was found. Reaction times were shortest in blocks 4 and 6. Reaction times in block 5 were slightly longer, the block with the shortest presentation times. This appears to be the normal pattern in athletes (Nederhof *et al.*, 2007).

The effect of reason for missing data was different between the two tests. The four female rowers who withdrew from the study were significantly slower on the finger pre-cueing task. This factor did not moderate the relationship between perceived performance and reaction time. Although the deselected rowers were not significantly slower on the determination test, this factor did moderate the relation between perceived performance and reaction time in the action mode of the determination test. For deselected rowers, no relation between perceived performance and reaction time was observed, whereas for the other rowers a significant negative relationship was observed.

Other moderators, not investigated in this study, might also be present, such as motivation. It could be hypothesized that athletes with low intrinsic but high extrinsic motivation for sports participation are less interested in using monitoring tools such as training diaries, questionnaires or reaction time tasks. Perfectionism could also be hypothesized to be a moderator. Athletes who are less of a perfectionist might have greater variability in their reaction

times, which could weaken the relationship with perceived performance.

Additionally, situational factors such as caffeine intake or sleep could have influenced the results. Future studies should investigate whether it is necessary to strictly monitor situational factors. These results would have major implications for the practical use of reaction time tasks for monitoring athletes' responses to training.

In the light of two earlier studies (Nederhof *et al.*, 2007; Rietjens *et al.*, 2005), it is surprising that a relationship between reaction time and perceived performance was found on the determination test but not on the finger pre-cueing task. In both studies, doubling the training load resulted in longer reaction times on the finger pre-cueing task. Apparently, the finger pre-cueing task is sensitive to sudden large changes in training load but not to small changes in perceived performance. For the determination test, the opposite might be true. A relation with small changes in perceived performance was found in the present study, but no changes in reaction times on the determination test were found after high load training (Nederhof *et al.*, 2007).

Apparently, some essential differences exist between the tests. The determination test is a complex reaction time task during which participants have to make manual reactions to five visual stimuli, pedal reactions to two other visual stimuli, and a manual reaction to an auditory stimulus. In the reaction mode, two of the visual/manual stimulus response combinations should be inhibited. Thus, an emphasis is placed on stimulus identification (Schmidt & Lee, 2005). The finger pre-cueing task is a complex reaction time task with four visual/manual stimulus response combinations. In three of four conditions, a pre-cue reduces the number of options to two. Thus, the emphasis of the finger pre-cueing task is on selective stimulus detection and on selective response preparation (Adam & Pratt, 2004). It is unclear how the different aspects of information processing are influenced by changes in perceived performance. In future studies, unravelling this question should be central.

Additionally, one would have to investigate how perceived performance, actual performance, and training status are related. For practical reasons, it was not possible to adequately assess actual performance in the present study. Assessing actual rowing performance was not possible due to different training modalities in autumn, winter, and the racing season in spring and early summer. Additionally, assessment of on-water rowing performance is not reliable due to varying weather conditions (Coen, Urhausen, & Kindermann, 2003). Assessing ergometer performance would have been possible in

autumn and winter, but the coaches did not agree on ergometer performance assessment in the racing season. They anticipated too much interference with the training and racing schedules.

Another question that should be addressed is whether it is necessary to assess actual performance for monitoring training status. Rietjens and colleagues (2005) showed that mood states as well as reaction times can change before changes in performance can objectively be assessed. Changes in subjective measures have been reported before the occurrence of performance decrements in previous studies (Coutts, Wallace, & Slattery, 2007; Hooper, Mackinnon, Howard, Gordon, & Bachmann, 1995; Kellmann & Gunther, 2000; Urhausen, Gabriel, Weiler, & Kindermann, 1998). Also, from clinical observations we know that patients often report subjective performance decrements while they are unable to report decrements in actual performance.

Conclusion

We conclude that the determination test is a useful test for monitoring rowers' perceived performance, but that several practical issues should be resolved, including the effect of repeated assessment. The finger pre-cueing task seems to be a less suitable tool for monitoring athletes as no relation with perceived performance was observed.

Acknowledgements

The authors thank all rowers and their coaches for their cooperation. We also thank Dr. M.A.J. van Duijn for her help with multilevel analysis. The present work was supported by a grant of the Dutch Ministry of Health, Welfare and Sport.

References

- Adam, J. J., Hommel, B., & Umiltà, C. (2003). Preparing for perception and action (I): The role of grouping in the response-cueing paradigm. *Cognitive Psychology*, 46, 302–358.
- Adam, J. J., & Moresi, S. (2007). Response preparation with static versus moving hands. *Brain and Cognition*, 65, 252–259.
- Adam, J. J., & Pratt, J. (2004). Dissociating visual attention and effector selection in spatial precueing tasks. *Journal of Experimental Psychology: Human Perception and Performance*, 30, 1092–1106.
- Coen, B., Urhausen, A., & Kindermann, W. (2003). Sport specific performance diagnosis in rowing: An incremental graded

- exercise test in coxless pairs. *International Journal of Sports Medicine*, 24, 428–432.
- Coutts, A. J., Wallace, L. K., & Slattery, K. M. (2007). Monitoring changes in performance, physiology, biochemistry and psychology during overreaching and overtraining in triathletes. *International Journal of Sports Medicine*, 28, 125–134.
- Goldstein, H., Rasbash, J., Plewis, I., Draper, D., Browne, W., Yang, M., et al. (1998). *A user's guide to MLwiN*. London: Multilevel Models Project, Institute of Education, University of London.
- Halson, S. L., & Jeukendrup, A. E. (2004). Does overtraining exist? An analysis of overreaching and overtraining research. *Sports Medicine*, 34, 967–981.
- Hooper, S. L., Mackinnon, L. T., Howard, A., Gordon, R. D., & Bachmann, A. W. (1995). Markers for monitoring overtraining and recovery. *Medicine and Science in Sports and Exercise*, 27, 106–112.
- Kellmann, M., & Gunther, K. D. (2000). Changes in stress and recovery in elite rowers during preparation for the Olympic Games. *Medicine and Science in Sports and Exercise*, 32, 676–683.
- Meeusen, R., Duclos, M., Gleeson, M., Steinacker, J., Rietjens, G., & Urhausen, A. (2006). Prevention, diagnosis and treatment of the overtraining syndrome. *European Journal of Sport Science*, 6, 1–14.
- Miller, J. (1982). Discrete versus continuous stage models of human information processing: In search of partial output. *Journal of Experimental Psychology: Human Perception and Performance*, 8, 273–296.
- Nederhof, E., Lemmink, K. A. P. M., Visscher, C., Meeusen, R., & Mulder, Th. (2006). Psychomotor speed: Possibly a new marker for overtraining syndrome. *Sports Medicine*, 36, 817–828.
- Nederhof, E., Lemmink, K. A. P. M., Zwerver, J., & Mulder, Th. (2007). The effect of high load training on reaction time in cyclists. *International Journal of Sports Medicine*, 28, 595–601.
- Neuwirth, W., & Benesch, M. (2003). *Determination test*, Release 31.00. Moedling, Austria: Dr. G. Schufried Ges.m.b.H.
- Raedeke, T. D., & Smith, A. L. (2001). Development and preliminary validation of an athlete burnout measure. *Journal of Sport and Exercise Psychology*, 23, 281–306.
- Rietjens, G. J. W. M., Kuipers, H., Adam, J. J., Saris, W. H. M., van Breda, E., van Harmont, D., et al. (2005). Physiological, biochemical and psychological markers for overreaching: Early markers for overreaching. *International Journal of Sports Medicine*, 26, 16–26.
- Schmidt, R. A., & Lee, T. (2005). *Motor control and learning: A behavioral emphasis* (4th edn). Champaign, IL: Human Kinetics.
- Snijders, T. A. B., & Bosker, R. J. (1999). *Multilevel analysis: An introduction to basic and advanced multilevel modelling*. London: Sage.
- Urhausen, A., Gabriel, H. H., Weiler, B., & Kindermann, W. (1998). Ergometric and psychological findings during overtraining: A long-term follow-up study in endurance athletes. *International Journal of Sports Medicine*, 19, 114–120.
- Urhausen, A., & Kindermann, W. (2002). Diagnosis of overtraining: What tools do we have? *Sports Medicine*, 32, 95–102.
- Uusitalo, A. L. T. (2001). Overtraining: Making a difficult diagnosis and implementing targeted treatment. *Physician and Sportsmedicine*, 29, 35–50.