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Title: Development and validity of the Subjective Training Quality scale

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Ethical Approval

Ethical approval was provided by the University of Technology Sydney Human Ethics Committee (both Parts One and Two, ETH18-2368).

Abstract

This study aimed to define, develop, and validate a subjective scale of training quality. Two related studies were used to 1) define training quality and 2) develop and validate a subjective scale. Part One: a purposive sample of 15 sub-elite (i.e., national) and elite (i.e., international) swimmers participated in one, 20-30-min semi-structured interview. Thematic analysis of interview responses established three constructs to define training quality. These were the physical, technical, and mental aspects of training. Part Two: development of the Subjective Training Quality (STQ) scale based on the three constructs identified in Part One. 252 sub-elite and elite athletes, across eight sports completed the STQ scale. Cronbach's alpha (α) assessed internal consistency, histogram plot analysis assessed face validity, and confirmatory factor analysis (CFA) compared physical, technical, and mental constructs with training quality. Root mean square error of approximation (RMSEA) and standardised root mean square residual (SRMR) evaluated CFA quality of fit. Physical, technical, and mental constructs demonstrated a high 'acceptable' level of internal consistency (α=0.85) and excellent face validity. Comparatively, the CFA quality of fit was 'excellent' (RMSEA=<0.01 'good', SRMR=0.00 'perfect'). The STQ scale demonstrated excellent internal consistency and face validity, establishing capacity to monitor training quality. The STQ scale could be used in conjunction with traditional training monitoring tools to provide additional insight into athlete's training quality. Further investigation is required to determine how the STQ scale may interact with subjective and objective training performance measures, and how it could be incorporated into daily training monitoring.

Highlights

- Athletes perceive the subjective training quality (STQ) scale adequately represents the physical, technical, and mental constructs of training quality.
- Excellent internal consistency and confirmatory factor analysis fit demonstrates the STQ scale is an effective tool to monitor training quality.
- With additional validation, the STQ scale could be used in conjunction with traditional load monitoring tools to provide greater insight to an athlete's training response, and subsequently inform training prescription.

Introduction

Coaches and sport science practitioners employ various monitoring tools to measure training performance to inform training planning and prescription. Typically, primary methods to measure training performance directly assess training quantity via physical outputs (i.e., duration, intensity, frequency). These physical measures are categorised as either internal (i.e., the relative biological stressor imposed during training or competition), or external (i.e., objective measures of work performed, independent of internal load).[1] However, these training monitoring methods have various challenges, including the requisite for valid and reliable devices and a high level of skill to complete the often complex interpretation of results.[1] Furthermore, traditional routine monitoring tools provide sensitive measures of changes in training quantity (i.e., global positioning systems) and internal training response (i.e., heart rate),[2,3] yet they do not directly assess training 'quality'. As a result, these objective assessments of training are often used as surrogate indicators of training quality. However, focussing solely on physical training outputs and disregarding other training quality aspects,

may lead to incorrect interpretations of training performance or success, subsequently negatively impacting training prescription.

Despite being common in the training vernacular for coaches and athletes, training quality has not been previously defined. Training quality has been implied in previous research stating reductions in soreness and fatigue could optimise training quality and has been indirectly assessed via an athlete's ability to meet prescribed physical objectives.[4,5] While this can provide insights into the physical effectiveness of training, the ability to identify all aspects of training quality itself is limited. Indeed, training quality is not limited to measures of intensity or duration. Athletes also need to maintain well-developed skills to achieve peak performance.[6] The level of emphasis placed on technical quality (e.g., skill progression, movement efficiency) will differ with various sporting demands, nevertheless, many coaches rely on their intuition and experience through athlete observation to determine training aspects, such as technical performance.[7] The mental component of an athlete's training is a further aspect of training performance that is overlooked with traditional monitoring tools. Currently, there are no measures to identify an athlete's mental engagement with training (e.g., motivation, attention), and instead tools often examine an athlete's mood or recovery status surrounding training.[8] It is therefore important these various aspects of sporting performance such as technical, tactical, and mental aspects (i.e., quality), are evaluated equally within a training session alongside training quantity. Given training quality is not limited to objective physical measures, quality may be more appropriately assessed subjectively by those with contextual understanding of the training demands.

The construct of training quality is defined here as an athlete's capacity to complete a training session to the desired level. As outlined, training quality must be differentiated from quantity to ensure an accurate representation of an athlete's training performance. Additionally, there remains no empirically validated assessment tool that can be implemented within the daily training environment to assess training quality.

The primary aim of this study was to define the construct of training quality, and subsequently develop and validate a subjective scale which could be used to assess an athlete's perceived training quality. The intention for development of a subjective scale was to create a brief tool that could be easily implemented and routinely used within the daily training environment. A subjective scale that provides insight into an athlete's training quality could be used in conjunction with traditional monitoring tools to improve coach and practitioner understanding of an athlete's training performance, and subsequently further inform training prescription.

Materials and Methods

Part One: Defining Training Quality Constructs

Selection of Participants

Purposive sampling was employed to select the swimmers for this study; with the swimmers' training characteristics, program, and competitive level used as the primary guide. It was anticipated these swimmers would provide valuable insights to the concept of training quality, which could then be expanded to, and considered by, athletes from additional sporting contexts.

Subjects

To define training quality, five sub-elite (i.e., national) and 10 elite (i.e., international) swimmers (22 ± 3 y, *n*=10 male, *n*=5 female) participated in one 20-30-min semi-structured interview following a regular swim training session. These swimmer interviews contained

questions relating to the swimmer's perceptions and use of recovery strategies in training and competition, in addition to their understanding of training quality. However, for the purpose of this study the information pertaining to training quality only, was used for this study. The fifteen swimmer interviews were considered sufficient to be inclusive of different ages, genders, and competitive level. Interviews were conducted in-season in the swimmer's home training environment. Inclusion criteria required consistent involvement in high-level training (i.e., minimum five sessions and two gym sessions per week) and currently competing at the national or international level. Written informed consent was obtained from athletes, in addition to verbal consent during interview recordings. Ethical approval was provided by the Human Ethics Committee (both Parts One and Two).

Design and Methodology

A semi-structured interview guide based on previous research[9] was created. Five pilot interviews on randomly selected individuals within the sporting sector (i.e., sport scientists – physiology and movement science practitioners, sport psychologist), lead to slight question modifications.[9] The interview guide was finalised, as previously identified,[10] to probe swimmers on their perceptions of training quality as an important aspect of improving swimming performance, and if the swimmers' training quality is currently assessed.

Swimmer responses were stored and interpreted via inductive thematic analysis[11] (NVivo v11.4, QSR International, 2017, Doncaster). Interview recruitment concluded once redundancy in the data was reached, determined to be the point at which no new themes relating to training quality were evident during the thematic analysis process.[12] Interviews were de-identified and transcribed verbatim by the primary investigator, with transcriptions sent to participants for the purpose of member checking (i.e., ensuring data credibility and accuracy).[12] Data transcription and familiarisation, code building, theme development, and theme consolidation and interpretation were conducted by the primary researcher. The research team reviewed identified codes and themes for relevance, and re-coded where necessary. Throughout the study period the primary researcher maintained a reflective journal to record idea progression and interview notes and to increase confirmability,[12] as recommended by Cahill and colleagues (2018).[13]

Results

Following completion of the inductive thematic analysis of the interview responses, the three main themes of physical, technical, and mental quality were established by the research team. The following are examples of some of the more common physical, technical, and mental quotes expressed by swimmers which were used to code these themes of training quality.

"Reaching the standards that you reached in previous, or in similar previous sets"-S14, *physical construct*

"whether you're hitting the times that you're supposed to be hitting, whether you're in the heart rate zone you're meant to be in, so that you're in the target of the session"-S11, *physical construct*

"feeling my stroke, keeping stroke rate, and distance per stroke and feeling long"-S7, *technical construct*

"feeling pretty relaxed I guess, and feeling determined and driven"-S6, *mental construct*

"I think mentally you have to be pretty much there to want to do it as well. I think that's a big factor in swimming that people don't really think about as well. Your mind can control what you really want to do."-S10, *mental construct*

Part Two: Development and Assessment of the Training Quality Measurement Tool

Subjects

This study used an exploratory research design to develop and assess the Subjective Training Quality (STQ) scale. A purposive sample of 252 sub-elite to elite athletes (21 ± 2.11 y), comprising 127 males and 125 females, participated in either an online (Qualtrics, 2002, Utah) or paper-based version of the STQ scale. Recruitment was conducted according to previous research requiring approximately 100 respondents.[14-16] Participants were recruited from 8 sports within Australia during the five month data collection phase (Figure 1). Inclusion criteria required participants to be consistently completing high-level training, and currently competing at the national or international level. Participants, guardians, and the organisation were provided with participant information prior to survey completion. Each organisation representative supplied written informed consent for their athlete's participation in the survery. Written informed parental consent was obtained from athletes under 18 y, and consent for athletes over 18 y was implied as part of scale completion.

Design and Methodology

The three primary themes derived in Part One prompted the development of the STQ scale questions, and were rated from 1 (strongly disagree) to 10 (strongly agree) (Supplementary Material 1). The STQ scale was completed following a regular sport-specific training session (not including strength sessions) across all participants. The training quality questions were prefaced with a demographics section, and indication of the session type (either aerobic/conditioning, technical/skills and drills, tactical, other). Before the training quality questions, written instructions indicated to athletes that a rating of '10' is provided when all targets and objectives for each question were successfully met. A rating of '10' did not necessarily equate to the athlete's best session, instead signified they had completed the session to the prescribed level or were satisfied with their ability to complete the session. RPE was also collected post-training, with both RPE and the STQ completed within 30-min post-exercise.[17,18]

Following completion of the three training quality questions, five Likert scale questions ranging from 1 (strongly disagree) to 5 (strongly agree) were used to assess face validity (i.e., a subjective assessment of whether an instrument measures what it intends to). The face validity questions comprise; "*the scale represents training quality*", "*the descriptive components (i.e., strongly disagree, strongly agree) help to decide on a rating*", "*the instructions help in understanding the scales*", "*Overall, the questionnaire is easy to understand*", and "*The online/paper format is easy to complete*."

Statistical Analysis

Initial reliability assessment was determined through internal consistency (i.e., the degree of interrelatedness between items)[19] of the three training quality questions, via use of Cronbach's alpha, as previously recommended.[16] Interpretation of Cronbach's alpha comprises ≥0.7 = 'acceptable'.[20,21] Content validity was determined through face validity using histogram plot analysis. Confirmatory factor analysis (CFA) was used to determine structural validity, by

assessing how closely the physical, technical, and mental ratings represent the construct of training quality, with RPE also included in this analysis process (Supplementary Material 2).[16] Root mean square error of approximation (RMSEA) and standardised root mean square residual (SRMR) were used to determine quality of fit within the CFA (R Core Team, 2018, Austria). RMSEA values <0.05 = 'good', 0.05-0.08 = 'adequate', 0.08-0.09 = "mediocre", >0.10 = 'unacceptable' with a 90% confidence interval lower boundary of <0.05 (ideally closer to 0) and upper boundary <0.08 = 'close fit'.[22] SRMR values of 0 = 'perfect', <0.05 = 'good', 0.05-0.08 = 'acceptable', >0.10 = 'unacceptable'.[22]

Results

The three training quality scales (i.e., physical, technical, mental) demonstrated a high 'acceptable' degree of internal consistency ($\alpha = 0.85$). When RPE is added to the analysis, internal consistency was reduced ($\alpha = 0.73$). Likewise, internal consistency decreases to an unacceptable level if any of the three training quality constructs are removed (Table 1).

CFA demonstrated similar results, with inclusion of RPE reducing the quality of fit (RMSEA = 0.09 'mediocre' 90% confidence interval 0-0.088, SRMR = 0.01 'good'). Comparatively, CFA of the three training quality constructs alone resulted in superior quality of fit (RMSEA = <0.01 'good' 90% confidence interval 0-<0.01, SRMR = 0.00 'perfect') (Table 2). Excellent mean Likert scores of 4 or 5, were evident across all five face validity questions, demonstrating the athletes agreed with the statements, implying the scale adequately measures training quality (Figure 2).

Discussion

The STQ scale demonstrated a high degree of internal consistency and excellent face validity across the three constructs, suggesting the scale has potential to be a useful training quality monitoring tool. There is scope for the STQ scale to be used in conjunction with other more traditional monitoring tools to provide comprehensive understanding of an athlete's training. In contrast to previous training monitoring tools, this is the first scale to directly assess the perceived quality of an athlete's training session.

Confirmatory factor analysis demonstrated excellent quality of fit between the training quality latent variable and the physical, technical, and mental constructs. This result therefore indicates the three constructs (i.e., physical, technical, mental) as proposed by the swimmers in Part One of this study, adequately represent the concept of training quality. However, using such a specific group to define training quality reduces the possibility of exploring other training constructs that could also relate to quality. One such example is through the separation of tactical training quality from technical quality. Anecdotally, tactical quality comprises a large element in team sports, with individual sport athletes potentially placing greater emphasis on tactical quality during competition, as compared to training. Although the team sport athletes in this study agreed the scale represented training quality, it is possible tactical quality as a separate construct was overlooked at the time of survey completion. Moreover, mental and emotional engagement should be separated in future iterations of the STQ scale, due to the differences in mental (e.g., motivation) and emotional constructs (i.e., psychophysiological reactions to the environment).[23] It is therefore important for future research studies to investigate the relationship between additional training constructs (e.g., tactical or emotional), and training quality.

Physiological and performance variables are the traditional methods used to monitor training, providing an indication of session intensity. Traditional measurement tools do not provide information regarding technical and mental quality, meaning the physical construct of training is primarily captured, with changes in other components of training quality likely overlooked. The STQ scale could therefore be used concurrently to complement objective load monitoring tools. For example, objective measures of training might indicate an athlete completed a good quality session (e.g., via distance covered at the prescribed intensity), however due to residual fatigue the athlete sacrificed their technique to meet the physical demands. Furthermore, the STQ scale can be used to capture an athlete's motivation or attention levels, both of which are not currently accounted for regularly within training by traditional monitoring. The relationship between objective training measures and the STQ scale therefore requires further investigation, particularly due to previous studies demonstrating mixed associations between subjective and objective training load monitoring tools.[24]

The STQ scale could provide monitoring and assessment of training quality across an array of sports. Part Two of this study was conducted on both female and male athletes from a broad range of sports, making the initial validation and potential use of this scale applicable across various team athletes in addition to swimmers. In line with previous research, future research studies should assess the STQ scale's construct and cross-cultural validity, and reliability across additional sports, particularly individual sports (e.g., athletics, combat) not included in the current study (e.g., athletics), as the importance placed on the various constructs of the STQ scale will likely differ between sports.[25] Measuring an athlete's perceived quality may improve training prescription through enhanced understanding of perceived effort and output. For example, if an athlete is repeatedly reporting poor mental training quality, it is possible they are not coping with their current loading, life stressors, or team dynamics by which appropriate adjustments or interventions can be made.

Historically, RPE is used by an array of athletes, coaches, and sport science practitioners to monitor individual responses to various changes in training load. Although RPE is frequently implemented as an indicator of intensity and effort, the use of RPE to depict training quality has not been previously assessed. Within the current study, RPE was used as a comparison with the three training quality constructs to determine if it also alludes to the quality of an athlete's session. Given the internal consistency and CFA quality of fit were reduced when RPE was included, it would be inappropriate to use RPE to infer training quality. The quality of fit was likely reduced with inclusion of RPE as this scale was originally developed as a subjective measure of training intensity, with training quality encompassing more than intensity alone. If external and internal load monitoring tools are continuously emphasised and used as the only or primary measure of training performance, it is likely several contributing factors to a training session are overlooked, with priority often given to physical capacities. While these measures may indicate the physical quality of a session, this interpretation of training quality does not consider the complex array of constructs that comprise an athlete's training. Therefore, the combined use of the STQ and traditional monitoring tools such as the RPE scale could provide greater insight into an athlete's perceived effort and quality. Moreover, the internal consistency of the scale decreased when one of the three training quality constructs was removed, indicating all three constructs are required to denote quality.

Future studies should seek to consider how this scale may be used by coaches, where the coach rates the athlete according to the three training quality constructs. Comparison between the coach's and athlete's rating could highlight discrepancies in coach-athlete perceptions, therefore minimising potential barriers between the two and improving coach-athlete interactions. The predictive ability of the STQ scale should also be explored to determine

whether consistently high quality training sessions that meet the prescribed training loads, lead to superior performances. Similarly, the relationship between training quality and recovery must be examined, in which reduced training quality demands greater emphasis on adequate recovery. Moreover, recovery could be targeted to the construct of training that is reduced. For example, physical quality could be maintained through appropriate inclusion of hydrotherapy strategies; use of psychological skills training may improve mental quality; and technical quality may be maintained or improved through enhanced focus on drills and skills. Fluctuations in training quality could be indicative of future performance. Athletes, coaches, and sport scientists could therefore monitor training quality variability in relation to training load, and recovery (e.g., via fatigue and recovery status, subjective recovery questionnaires), however validation of this concept is required.

The assessment of construct validity, specifically through structural validity, of the STQ scale in relation to various objective training measures are essential. As concurrent validity (a form of criterion validity) compares the results of a test against the gold-standard instrument. Currently, there is no gold-standard objective or subjective form of measuring training quality. Therefore, construct validity, specifically structural validity, should be further explored for validation of the STQ scale. Examples of this validation between the STQ scale and various objective measures could include total distance, object release angle, or successful shots at goal. By using an individual's STQ scale results in comparison with their objective training outcomes, coaches and practitioners can identify potential discrepancies. Understanding the required frequency of use for the scale (i.e., how often the STQ would need to be used across a training week) is necessary to define how the scale may be used by athletes, coaches, and sport science practitioners in the daily training environment. Lastly, additional surveys and interviews of athletes and coaches should be conducted across a variety of sports to further confirm the training quality constructs. Future research in the aforementioned areas is crucial for the implementation of the STQ scale. Therefore, future longitudinal research studies assessing individual responses across multiple training days and additional sports, and the relationship with performance outcomes, are warranted. Further validation assessment using the COSMIN checklist is required prior to use of the STQ scale within the applied setting.[19,25]

Conclusions

Training quality, defined earlier as an athlete's capacity to complete a training session to the desired level, could now be more specifically defined as an athlete's capacity to meet their physical, technical, and mental training objectives. The STQ scale demonstrated excellent internal consistency, construct, and face validity with training quality, highlighting the potential of this scale as a valuable determinant of quality. This is the first study to assess and define training quality directly, and to develop a monitoring tool that could be used to assess training quality. With further validation, it is possible this scale could be regularly used in the daily training environment to determine an athlete's perceived training quality, which may improve training prescription and outcomes. As demonstrated in the current study, inclusion of RPE decreased the STQ scale internal consistency and CFA results, therefore coaches and sport science practitioners should ensure the RPE scale is only used for its intended purpose; as a measure of perceived exertion and not of training quality. Future research to assess the validity of the STQ scale is required, including comparison with objective markers of training quality and coach responses. The required frequency of use should also be assessed via consultation with practitioners.

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Figure Legends

Figure 1. Distribution of sports and athlete participant numbers, F = female, M = male

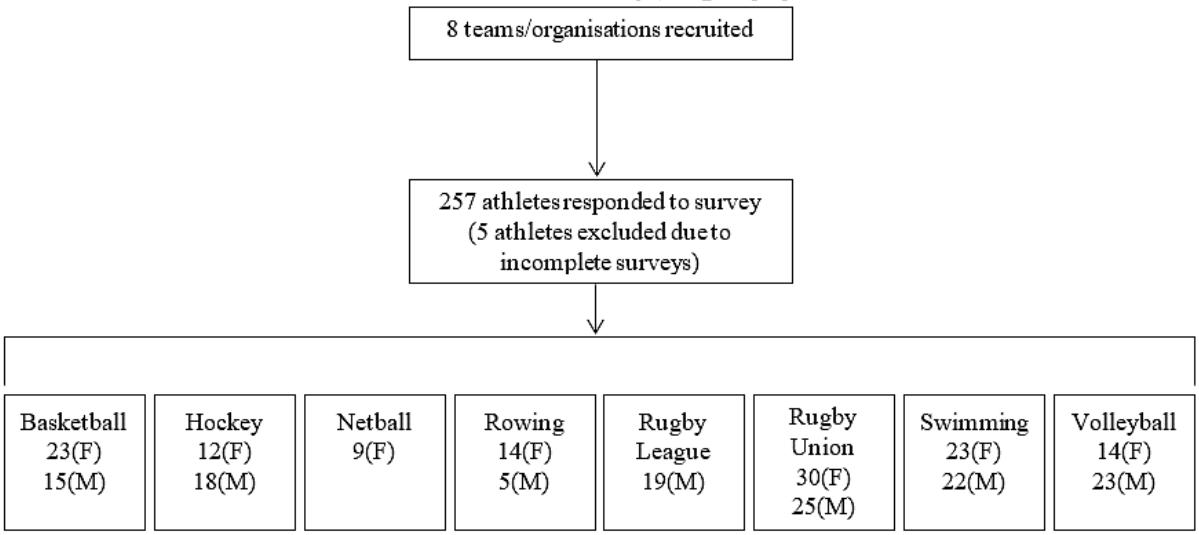


Figure 2. Mean face validity Likert outcomes of the STQ scale.

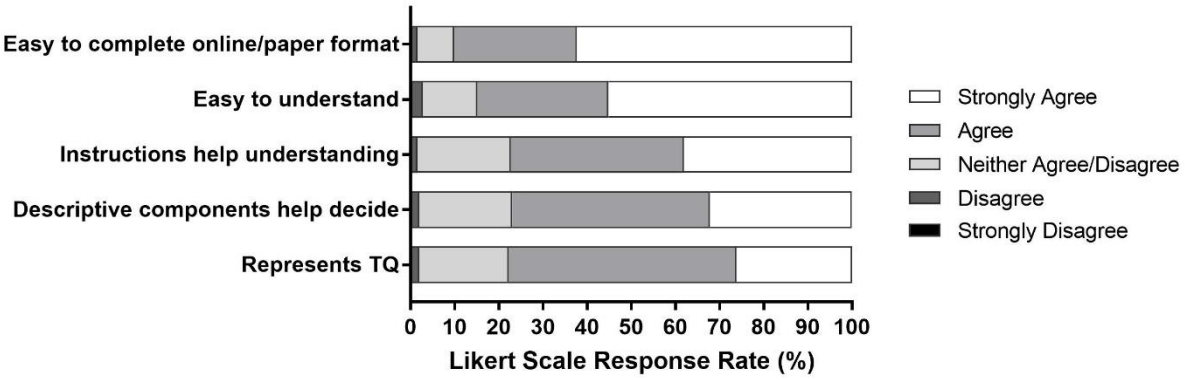


Table 1. Cronbach's alpha (α) score if a construct of training quality is removed.

Training Quality Construct	Cronbach's Alpha (α) When Removed
Physical	0.58
Technical	0.59
Mental	0.60

Table 2. Confirmatory Factor Analysis (CFA) variance estimates, and standard error (SE) scores when RPE is excluded from the analysis process.

Training Quality Construct	Variance Estimate	SE
Physical	1.569	0.102
Technical	1.452	0.098
Mental	1.525	0.118

I met my physical training objectives in this session.

(e.g. prescribed training intensity, training distance, target time, sets and reps, able to give your best effort)

	1 Strongly Disagree	2	3	4	5	6	7	8	9	10 Strongly Agree
Physical quality	○	○	○	○	○	○	○	○	○	○

I met my technical training objectives in this session.

(e.g. body position, foot strike, movement efficiency, technique, execution of drills/skills/tactics)

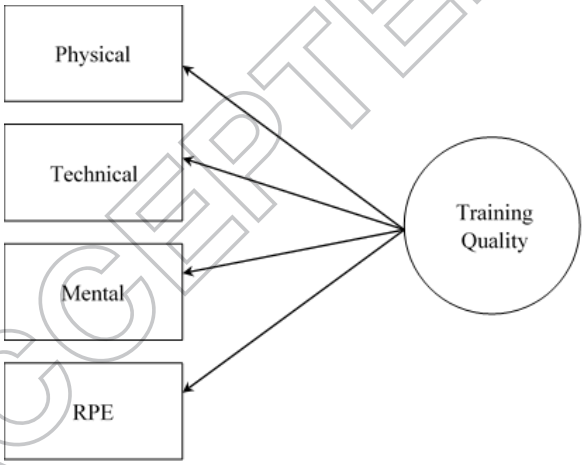
	1 Strongly Disagree	2	3	4	5	6	7	8	9	10 Strongly Agree
Technical quality	○	○	○	○	○	○	○	○	○	○

I was mentally and emotionally engaged in this session.

(e.g. focussed, attentive, under control, switched on, motivated)

	1 Strongly Disagree	2	3	4	5	6	7	8	9	10 Strongly Agree
Mental quality	○	○	○	○	○	○	○	○	○	○

Suppl 1. Subjective Training quality (STQ) scale questions.



Suppl 2. Single factor, confirmatory factor analysis for training quality (latent variable) and associated indicator variables (physical, technical, mental, RPE).