ITF COACHING & SPORT SCIENCE REVIEW

International Tennis Federation
www.itfcoachingreview.com
December 2022. 30th Year. Issue 88. 4-9
ISSN 2225-4757
https://doi.org/10.52383/itfcoaching.v30i88.329

Distribution of intensities and quantification of training load in young U15 elite tennis players

Marie-Florine Michel, Jean-Marc Duboscq, Sébastien Ratel, Laurent Schmitt, Alexandre Hidalgo & Cyril Brechbuhl

French Tennis Federation, France.

ABSTRACT

The objectives of this study were to quantify training intensity as a function of time spent in three metabolic intensity zones, to compare programmed intensity, measured intensity (heart rate) and estimated intensity (RPE: Rating Perceived Exertion), and then to determine the training loads in 8 high level male tennis players. No difference was found between the time programmed in zones 1 (69.9 ± 4.8 %) and 2 (22.8 ± 4.4 %) and the time spent at a heart rate below Ventilatory Threshold 1 (VT1) (78.9 ± 9.4 %) and between VT1 and Ventilatory Threshold 2 (VT2) (18.3 ± 9.5 %) ($p > 0.05$). Thus, they trained in accordance with the programmed and recommended intensity distribution by adopting a "pyramid" pattern of intensity distribution. Furthermore, significant differences were found between the percentages of scheduled time and the percentages of perceived time (RPE) for all zones ($p < 0.05$). The overestimation of the estimated intensity can be explained by their age and the intermittent nature of tennis. Finally, we can note that the programmed training load is like that observed for players of the same age and level.

Key words: intensity distribution, training load, RPE, heart rate.

Received: 13 June 2022

Accepted: 25 July 2022

Corresponding author: Cyril Brechbhul. Email: cyril.brechbuhl@fft.fr

INTRODUCTION

In addition to the mental, technical-tactical and perceptive-cognitive qualities that the athlete must possess, tennis performance requires a complex interaction between the energy pathways (aerobic and anaerobic) (Fernandez et al., 2006) and complete physical qualities (speed of movement, endurance, explosive strength, coordination, agility, flexibility) (Girard et al., 2018). The combined development of these different capacities requires methodological skills on the part of the coaches. Several studies have quantified the intensity of training in different types of endurance athletes (Esteve-Lanao et al., 2007; Seiler & Kjerland, 2006). To quantify training intensity, coaches usually rely on physiological and subjective indicators and divide the range of training intensities into 3 or 5 distinct zones. The 3-zone model and the 5-zone model have common intensity points around the lactic (2 and 4 mmol.L-1) and ventilatory thresholds (Seiler, 2010) (Figure 1).

The model most commonly used by athletes, particularly in tennis, is the so-called "polarised" model (Stöggl & Sperlich, 2014). In this model, 75-80% of the sessions are performed at low intensities, i.e. less than or equal to the first ventilatory threshold (Zone 1) and 15-20% at intensities, known as very high, greater than or equal to the second ventilatory threshold (Zone 3) (Laursen, 2010; Stöggl & Sperlich, 2014; Treff et al., 2019). In addition to the distribution of intensities, coaches also seek to achieve a sufficiently high training load while limiting the risk of injury (Halson, 2014). A variety of methods have been proposed to measure training

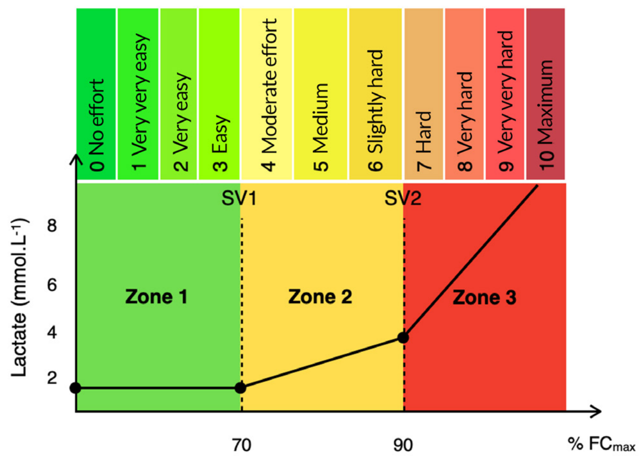

Figure 1. *The three-intensity zone model, including RPE equivalence, based on the identification of lactic and ventilatory thresholds (SV1 and SV2).*

load. The principle common to the various approaches to quantifying training load is to multiply a volume indicator by a difficulty or intensity indicator of the training (Foster et al., 2001; Impellizzeri et al., 2004). They are divided into two approaches: on the one hand, quantification methods based on physiological variables (heart rate (HR), lactatemia, maximum oxygen consumption (VO2max)); on the other hand, methods using psychometric variables (difficulty of perceived effort, called RPE) (Seiler, 2010). Heart rate is a parameter that can be measured quickly, non-invasively, easily implemented in training and applicable to a large number of players at the same time (Buchheit, 2014). In addition, numerous methods for quantifying training load, based on heart rate, have emerged, notably the "Training Impulse" method (TRIMPS) (Banister, 1991; Edwards, 1993; Lucia et al., 2003). However, the measurement of heart rate as the only tool for analysing training load requires a certain amount of expertise when analysing and interpreting the data collected. Other physiological measures, such as lactate and VO2max measurements, are not practical in training situations and even less so in competition. In order to quantify the training load, RPE is the most frequently used method (Halson, 2014). The RPE, developed by Borg, allows the athlete to provide information about his or her perceived effort after training or competition on a Borg scale (Borg, 1998). Chen et al. (2002) have indicated that the RPE is a valid means of assessing exercise intensity. In addition, the assessment of perceived exertion is widely recognised as one of the most appropriate methods for monitoring tennis load (Coutts et al., 2010; Gomes et al., 2011). The method proposed by Foster et al. (2001) called session-RPE (sRPE), consists of multiplying the overall perceived difficulty of the session (RPE taken on a modified Borg CR-10 scale) by the total duration of the session (in minutes) to obtain a score expressed in arbitrary units (AU) that quantifies the training load. However, no published study has described the distribution of training intensity and training loads in high-level U15 tennis players. The main objective of this study was therefore to quantify the distribution of daily training intensity and training loads in young tennis players. We also compared the distribution of training intensity using two independent measures: heart rate and perceived effort during training sessions. We hypothesised that players would train in a 'pyramid' training pattern, where relatively little training would be performed at intensities above the second ventilatory threshold.

MATERIALS AND METHODS

Players

Eight male tennis players (age: 13.8 ± 1.0 years; height: 166.1 ± 12.8 cm; body mass: 51.5 ± 11.0 kg) with an International Tennis Number (ITN) ranging from 2 to 3 (ITN 2 = 2 players; ITN 2 = 6 players) and belonging to the Pôle France (integrated into the CREPS of Poitiers), participated in this study. The recruited tennis players, who were volunteers, were in good health and free of any type of chronic injury. After receiving information about the procedures used in this study, the participants and their legal representatives signed an informed consent form.

Procedures

At the beginning of the season, all players completed the TEST procedure which determined ventilatory thresholds for tennis training (Brechbuhl et al., 2016a, 2016b). Then for 12 weeks (February to May) of the 2022 season, Heart Rate (HR) and Rating of Perceived Exertion (RPE) were collected during training sessions, simulated matches, and official matches. The training programme was planned by the tennis coaches for each player according to the tournaments, the fitness level, possible injuries, and the technical and physical goals of each player. The training sessions took place 70% of the time on outdoor clay, 25% of the time on indoor GreenSet® and 5% of the time on outdoor GreenSet®. Each tennis player performed 11.5 ± 2.2 technical/tactical training sessions per week ranging from 30 minutes to 3 hours in duration for each training period (morning or afternoon). Heart rate data were collected during each training session using a Polar H10 heart rate monitor® (Polar Electro, Kempele, Finland), except for weeks 9 and 10 (Figure 2B), when data could not be collected (International Tournament). In addition, every evening, each athlete recorded their RPE for the whole of each session (morning and/or afternoon) using the modified Borg CR-10 scale (Foster et al., 2001 ; Gomes et al., 2015 ; Haddad et al., 2017). Players were asked to choose a score between 0 (rest) and 10 (maximum effort).

DATA PROCESSING

The distribution of intensity

Training duration was determined using the coaches' planned training schedule. Heart rate data was only considered when the player wore the heart rate monitor at least 75% of the time for each week. This data was recorded using Polar Team System software® (Polar Electro, Kempele, Finland) which calculates the percentage of time spent in each of the predefined HR zones. This data was then used to determine the intensity of each training week in three intensity zones (Zone 1 ≤ SV1; Zone 2 > SV1 and < SV2; Zone 3 ≥ SV2). The two ventilatory thresholds, for tennis training, were established on the basis of the results of the TEST procedure (Brechbuhl et al., 2016a, 2016b). Based on the results of a study of 14-15 year old triathletes with a comparable training volume (Birat et al., s. d.), SV1 was set at 70% HRmax and SV2 was set at 90% HRmax for all non-tennis training for all players. For the RPE data, the CR-10 scores were divided into three zones: Zone 1 ≤ 4; Zone 2 > 4 and < 7; Zone 3 ≥ 7, according to Seiler & Kjerland (2006). Subsequently, the time spent in each RPE zone per week was calculated by summing the duration of each session for each zone. The percentage of time spent in each heart rate-based and RPE-based training zone was compared to the coaches' programmed intensity distribution.

The training load

The results of the Gomes et et al. (2015) study confirm the validity and, therefore, the possibility of using the session-RPE (sRPE) method to quantify training load in tennis. The daily training load or sRPE is calculated as the product of intensity (half-day sRPE) and volume (the duration of the activity) (Foster et al., 2001). Then the weekly training load is obtained by summing the daily sRPEs for the week.

DATA ANALYSIS

All data were expressed as mean ± standard deviation and were analysed using RStudio (RStudio v1.3.1093, US). The normality of the data distribution was checked by the Shapiro-Wilk test. The distribution of training intensity was compared for each assessment method (programmed (trainer) vs. measured (HR) vs. estimated (RPE)) and for each intensity zone (Zone 1 vs. Zone 2 vs. Zone 3) using a two-factor ANOVA (assessment method and intensity zone). If a significant difference was found, a pairwise comparison (Bonferroni method) was used as a post-hoc test. The significance level was set at $p < 0.05$ for all analyses.

RESULTS

On average, each week, the scheduled intensity is distributed as follows: more than 9 h of training in Zone 1, about 3 h in Zone 2 and 1 h in Zone 3 (Figure 2A). The heart rate data show that the players spent on average just under 12 h in Zone 1, just over 2 h in Zone 2 and 30 min in Zone 3 each week (Figure 2B). Regarding the distribution of intensities achieved according to the RPE, the players perceived their effort, on average per week, more than 4 h in Zone 1, about 5 h in Zone 2 and 3 h in Zone 3 (Figure 2C).

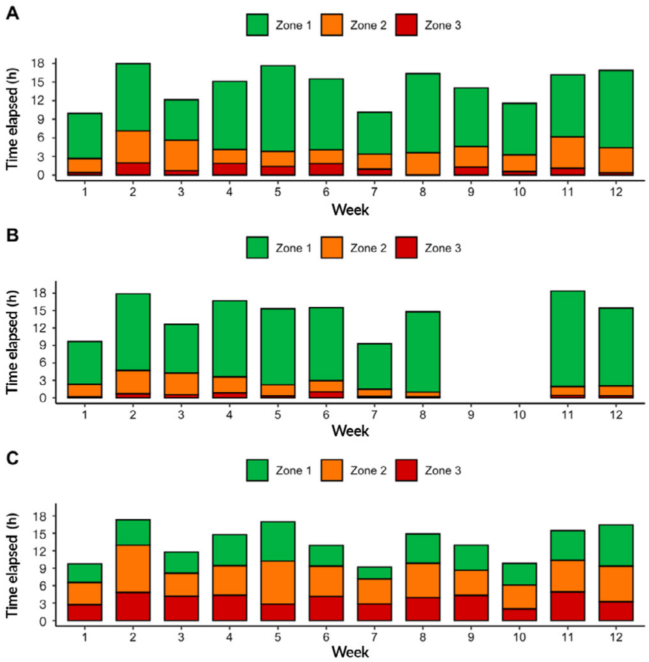

Figure 2. *Average distribution of training intensity (h) for all players over 12 weeks (A: Scheduled intensity, B: Measured intensity and C: Estimated intensity).*

The average percentage of time spent in each of the three intensity zones according to the three assessment methods (programmed (trainer) vs. measured (HR) vs. estimated (RPE)) is presented in Figure 3. Statistical analysis revealed a main effect of the "Zone" factor ($p < 0.05$), no effect of the "Evaluation method" factor and a significant interaction between these two factors ($p < 0.05$). A significant difference was found between the percentage of time scheduled in Zone 1 (69.9 ± 4.8%) and the percentage of time perceived by the players in Zone 1 (Intensity ≤ 4 on the modified Borg CR-10 scale) (36.0 ± 14.0%) ($p < 0.001$). No difference was found between the time scheduled in Zone 1 and the time spent at or below SV1 (78.9 ± 9.4 %) ($p > 0.05$). A significant difference was found between the percentage of time programmed in Zone 2 (22.8 ± 4.4 %) and the percentage of time perceived by the players in Zone 2 (Intensity between 4.5 and 6.5) (38.3 ± 8.1 %) ($p < 0.01$) No difference was found between the time programmed in Zone 2 and the time spent at a heart rate between SV1 and SV2 (18.3 ± 9.5 %) ($p > 0.05$). Furthermore, significant differences were found between the percentage of time programmed in Zone 3 (7.3 ± 2.0 %) and the percentage of time spent at a heart rate greater than or equal to SV2 (2.7 ± 2.0 %) ($p < 0.001$) and that perceived at an intensity ≥ 7 (25.7 ± 12.0 %) ($p < 0.05$).

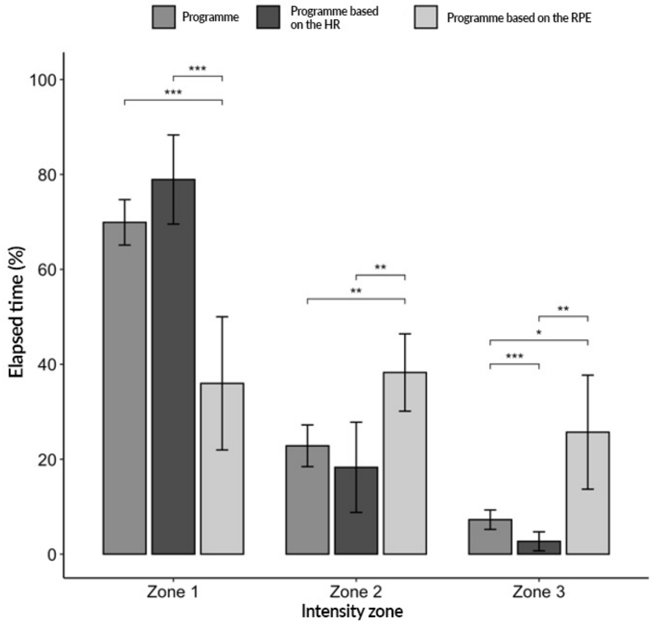

Figure 3. *Average intensity distribution of all players over 12 weeks of training and matches based on two different quantification methods: Measured intensity (Heart Rate) and estimated intensity (RPE). * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.*

As the training programme was planned for each player according to tournaments (singles and doubles matches), fitness and injuries, we chose to represent the training load of two players, representative of the inter-individual variability. In total, 18 matches were played with an average win rate of 61.1 ± 15.1 % for player 1 (Figure 4A) and 9 matches were played with an average win rate of 22.2 ± 29.9 % (Figure 4B). The average weekly training load during the 12 weeks was 5445 ± 2016 AU (Arbitrary Units), ranging from 1935 AU to 9375 AU for player no. 1 (Figure 4C) and 4381 ± 1919 AU, ranging from 1950 AU to 7710 AU for player no. 2 (Figure 4D). The training load is well individualised, but it did not have the expected results in terms of winning for player no. 2. Furthermore, we found that there is no higher training load in the training weeks compared to the match weeks.

DISCUSSION

The aim of this study was to quantify the distribution of daily training intensity with different assessment methods, and to follow the evolution of training load in young elite tennis players from programmed intensity revealed that a pyramidal distribution, whereby 70-75% of the total training volume is performed at low intensities (Zone 1) and about 5-10% at very high intensities (Zone 3), is proposed. This distribution has been suggested as one of the optimal training intensity distributions and one of the most frequently used in adult elite endurance athletes (Bourgois et al., 2019; Brechbuhl et al., 2017). The results observed via the heart rate monitor are similar to the training sessions programmed in Zone 1 (78.9 ± 9.4 %) and 2 (18.3 ± 9.5 %). These results are in line with those of the Baiget et et al. (2015) conducted with 20 high-level Spanish tennis players (age: 18.0 ± 1.2 years; gender: male) simulating tennis sets, where players spent on average 77% of the time in Zone 1 (below SV1), 20% in Zone 2 (between SV1 and SV2), and only 3% in Zone 3 (above SV2). As a result, the young male tennis players at

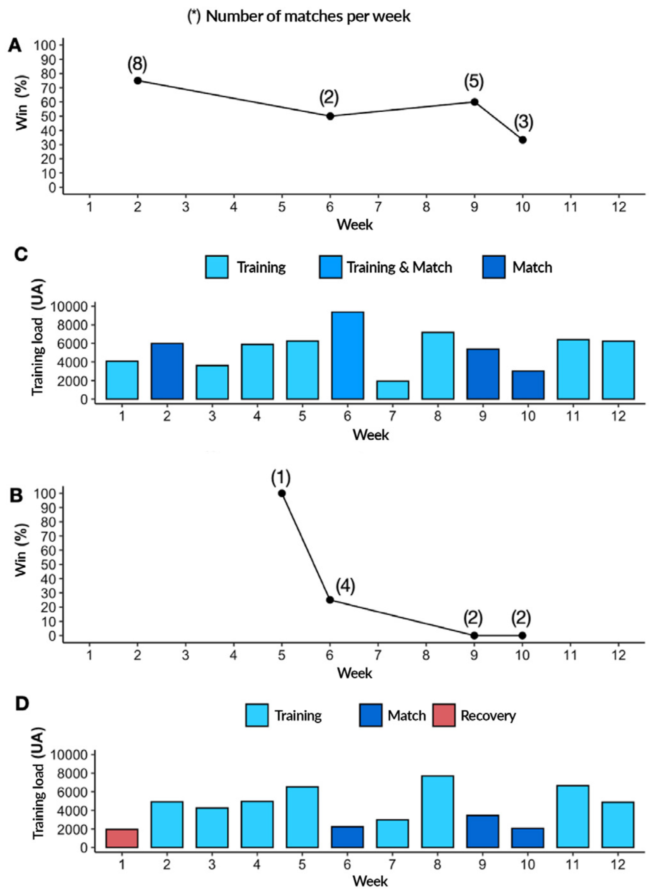

Figure 4. *Victory (%) (A & B) and training load distribution (AU) (C & D) of player #1 (A & C) and player #2 (B & D) over 12 weeks.*

Pôle France train in accordance with the programmed and recommended intensity distribution by adopting a "pyramid" model of intensity distribution. From a metabolic point of view, these young players, aged 14 on average, are in (or close to) their peak of rapid growth (Sempé & Pédron, 1971). Prior to puberty, children rely mainly on the aerobic pathway for energy production. However, during this pubertal growth peak, there is a transition to a greater use of the anaerobic pathways that produce metabolites that cause muscle fatigue (Kenney et al., 2021; Ratel & Blazevich, 2017). Therefore, from the peak of growth velocity, it is essential to offer a high volume of low intensity aerobic training (Zone 1) in order to delay fatigability, facilitate recovery and optimise technical work (Ratel, 2018). This is done using "polarised" and "pyramid" training models depending on the sporting objective of the season.

Concerning the distribution of intensities carried out according to the RPE, the players have a "homogeneous" perception of the time spent in each intensity zone (Zone 1: 35.0 ± 15.4 %; Zone 2: 38.5 ± 8.4 %; Zone 3: 26.4 ± 11.9 %). This means that sessions programmed in Zone 1 are in fact sessions where players feel in Zone 2 or even 3. This significant difference between the distribution of programmed intensities and that of the RPE results (Figure 2A & 2C) may be due to the intermittent nature of tennis. Indeed, this alternation of short high intensity efforts and short recovery breaks on an aerobic endurance background leads to a production and accumulation of muscle metabolites (e.g., ammonia, protons, lactate) which could contribute to increase peripheral sensations of fatigue (Mutch & Banister, 1983) and therefore RPE (St Clair Gibson & Noakes, 2004). This overestimation could also be explained by an increase in central sensations linked to the intermittence of the heart rate during repeated efforts. Thus, the fatigability of tennis training sessions would be underestimated if only heart rate is considered as an indicator of internal load. Another explanatory factor could be the age of the players. Indeed, Groslambert & Mahon (2006) found a poorer correlation between RPE and heart rate during incremental exercise in adolescents than in adults. Furthermore, peripheral factors (i.e., maximal lactate, maximal minute ventilation, and mechanical work output) appeared to explain only 36% of the variance in RPE measured with the CR-10 during intense exercise from childhood to adolescence (Bardin et al., s. d.). This suggests that other psychosocial factors may be important in estimating RPE during exercise. Thus, although RPE, which considers the involvement and intuition of each player, is a useful monitoring tool for the coach to simply assess the perceived effort of the session, it would be necessary to quantify the intensity of training with both physiological and psychometric variables in young categories.

Regarding training load, the average (respectively 5373 AU and 4381 AU for players #1 and #2) imposed over the 12 weeks is similar to that of young players in futsal (15.8 ± 0.8 years) (Moreira et al., 2013) and basketball (19 ± 1 years) (Moraes et al., 2017) where the training load does not exceed 6000 AU. In addition, the training loads of the technical/tactical sessions (512.5 ± 191 AU) are similar to those observed for Australian players aged 17 ± 1.3 years ranked 135 ± 22 in the International Tennis Federation junior and 1309 ± 370 in the Association of Tennis Professionals who had a load of 492 ± 304 AU (Murphy et al., 2015). However, some weeks (e.g., weeks 6 and 8 Figure 4) have training loads above 7000 AU. These high training loads are due to weeks with high volume sessions (more than 2 h training per session). Long training sessions are perceived as difficult because of their long duration, and the associated level of perceived exertion is multiplied by the duration of the effort (Foster et al., 2001). As a result, the duration of the effort is taken into account twice, which tends to overestimate the loads for high volume training situations (Martin, 2018). However, these weeks with high training loads are automatically followed by a week with a load of less than 4000 AU, which shows that the previous weeks are considered to plan the training in the most optimal way. We observe that the organisation of the training loads allowed half of the players to maintain good performance while minimising any risk of injury. In contrast, the other half of the players had a negative win percentage (n = 2) or did not play any official matches (n = 2) due to injuries. This suggests that the training load was not planned in the most judicious way. In order to reduce training-related injuries in the long term, Gabbett (2016). The importance of monitoring the training load is emphasised.

CONCLUSION

The present results show that young elite French tennis players train 70-75% of the time in a low intensity zone, about 20% in a moderate intensity zone and 3-5% in a high intensity zone. These data therefore demonstrate that a "pyramid" training model is used. In addition, the age of the players is a factor confirming the importance of aerobic work during training. However, the players overestimated the intensity of their efforts (moderate to intense intensities) compared to the prescribed training intensity and the actual training intensity (heart rate). This overestimation can be explained by the intermittent nature of tennis and the age of the players in this study. Therefore, it seems essential to couple heart rate with RPE in future studies. Furthermore, the programmed training load was like that observed for players of the same age at a high level. We can conclude that for half of the players, this planning allowed them to maintain good performance while minimising the risk of injury. The results presented here can therefore be seen as a first step towards the recognition of the necessary distribution of the actual training intensity performed by young tennis players. Tennis coaches will now be able to compare the training loads of their players with the results presented here. In addition, tennis coaches can use the current training monitoring methods adopted in the present study to verify the internal training load of their players. The use of such an approach should allow coaches to adjust the training load to avoid the phenomenon of 'overtraining'. As the current data are on young male players, further studies on female tennis players are needed. The use of heart rate variability monitoring can also complement the monitoring of individual physiological response over time (Schmitt et al., 2006).

CONFLICT OF INTEREST AND FUNDING

The authors declare that they do not have any conflict of interest and that they did not receive any funding to conduct the research.

REFERENCES

Baiget, E., Fernandez-Fernandez, J., Iglesias, X., & Rodríguez, F. (2015). Tennis Play Intensity Distribution and Relation with Aerobic Fitness in Competitive Players. *PLoS One*, *10*, e0131304. https://doi.org/10.1371/journal.pone.0131304

Banister, E. W. (1991). Modeling Elite Athletic Performance. In *Physiological Testing of Elite Athletes* (Human Kinetics.).

Bardin, J., Maciejewski, H., Diry, A., Droit-Volet, S., Thomas, C., & Ratel, S. (s. d.). Sex- and Age-related differences in the rating of perceived exertion after high-intensity rowing exercise during childhood and adolescence. *Laboratoire AME2P (UCA) et Fédération Française d'Aviron*.

Birat, A., Garnier, Y., Dodu, A., Grossoeuvre, C., Rance, M., Morel, C., Nottin, S., & Ratel, S. (s. d.). Suivi des adaptations physiologiques induites par l'entraînement en triathlon chez le jeune athlète. *Laboratoire AME2P (UCA) et Fédération Française de Triathlon (Données non publiées)*.

Borg, G. (1998). *Borg's perceived exertion and pain scales* (p. viii, 104). Human Kinetics.

Bourgois, J. G., Bourgois, G., & Boone, J. (2019). Perspectives and Determinants for Training-Intensity Distribution in Elite Endurance Athletes. *International Journal of Sports Physiology and Performance*, *14*(8), 1151-1156. https://doi.org/10.1123/ijspp.2018-0722

Brechbuhl, C., Girard, O., Millet, G. P., & Schmitt, L. (2016a). On the Use of a Test to Exhaustion Specific to Tennis (TEST) with Ball Hitting by Elite Players. *PLoS ONE*, *11*(4), e0152389. https://doi.org/10.1371/journal.pone.0152389

Brechbuhl, C., Girard, O., Millet, G., & Schmitt, L. (2016b). Stress test specific to tennis (Test) : Case study of an elite player. *ITF Coaching & Sport Science Review*, *24*(70), 27-30. https://doi.org/10.52383/itfcoaching.v24i70.217

Brechbuhl, C., Girard, O., Millet, G., & Schmitt, L. (2017). Towards polarized training in tennis? Usefulness of combining technical and physiological assessments during a new incremental field test. *ITF Coaching & Sport Science Review*, *25*(73), 27-31. https://doi.org/10.52383/itfcoaching.v25i73.303

Buchheit, M. (2014). Monitoring training status with HR measures: Do all roads lead to Rome? *Frontiers in Physiology*, *5*, 73. https://doi.org/10.3389/fphys.2014.00073

Chen, M. J., Fan, X., & Moe, S. T. (2002). Criterion-related validity of the Borg ratings of perceived exertion scale in healthy individuals: A meta-analysis. *Journal of Sports Sciences*, *20*(11), 873-899. https://doi.org/10.1080/026404102320761787

Coutts, A., Gomes, R., Viveiros de Castro, L. E., & Aoki, M. (2010). Monitoring training loads in elite tennis. *Revista Brasileira de Cineantropometria e Desempenho Humano*, *12*. https://doi.org/10.5007/1980-0037.2010v12n3p217

Edwards, S. (1993). *The heart rate monitor book.* (Polar Electro Inc).

Esteve-Lanao, J., Foster, C., Seiler, S., & Lucia, A. (2007). Impact of training intensity distribution on performance in endurance athletes. *Journal of Strength and Conditioning Research*, *21*(3), 943-949. https://doi.org/10.1519/R-19725.1

Fernandez, J., Mendez-Villanueva, A., & Pluim, B. M. (2006). Intensity of tennis match play. *British Journal of Sports Medicine*, *40*(5), 387-391; discussion 391.

Foster, C., Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., Parker, S., Doleshal, P., & Dodge, C. (2001). A new approach to monitoring exercise training. *Journal of Strength and Conditioning Research*, *15*(1), 109-115.

Gabbett, T. J. (2016). The training—injury prevention paradox: Should athletes be training smarter *and* harder? *British Journal of Sports Medicine*, *50*(5), 273-280.

Girard, O., Brechbuhl, C., Schmitt, L., & Millet, G. P. (2018). Evaluation et développement des ressources physiologiques du joueur de tennis. In *Tennis : Optimisation de la performance.* (p. 32-48). De Boeck Supérieur.

Gomes, R., Coutts, A., Viveiros de Castro, L. E., & Aoki, M. (2011). Physiological demands of match-play in elite tennis: A case study. *European Journal of Sport Science*, *11*, 105-109. https://doi.org/10.1080/17461391.2010.487118

Gomes, R., Moreira, A., Lodo, L., Capitani, C., & Aoki, M. (2015). Ecological Validity of Session RPE Method for Quantifying Internal Training Load in Tennis. *International Journal of Sports Science & Coaching*, *10*. https://doi.org/10.1260/1747-9541.10.4.729

Groslambert, A., & Mahon, A. (2006). Perceived exertion: Influence of age and cognitive development. *Sports medicine (Auckland, N.Z.)*, *36*, 911-928.

Haddad, M., Stylianides, G., Djaoui, L., Dellal, A., & Chamari, K. (2017). Session-RPE Method for Training Load Monitoring: Validity, Ecological Usefulness, and Influencing Factors. *Frontiers in Neuroscience*, *11*. https://www.frontiersin.org/articles/10.3389/fnins.2017.00612

Halson, S. L. (2014). Monitoring Training Load to Understand Fatigue in Athletes. *Sports Medicine (Auckland, N.z.)*, *44*(Suppl 2), 139-147. https://doi.org/10.1007/s40279-014-0253-z

Impellizzeri, F., Rampinini, E., Coutts, A., Sassi, A., & Marcora, S. (2004). Use of RPE-based training load in soccer. *Medicine and science in sports and exercise*, *36*, 1042-1047. https://doi.org/10.1249/01.MSS.0000128199.23901.2F

Kenney, L., Wilmore, J. H., & Costill, D. L. (2021). *Physiologie du sport et de l'exercice* (7e édition).

Laursen, P. B. (2010). Training for intense exercise performance: High-intensity or high-volume training? *Scandinavian Journal of Medicine & Science in Sports*, *20 Suppl 2*, 1-10. https://doi.org/10.1111/j.1600-0838.2010.01184.x

Lucia, A., Hoyos, J., Santalla, A., Earnest, C. P., & Chicharro, J. L. (2003). Giro, Tour, and Vuelta in the same season. *British Journal of Sports Medicine*, *37*(5), 457-459. https://doi.org/10.1136/bjsm.37.5.457

Martin, C. (2018). *Tennis Optimisation de la performance* (De Boeck Supérieur).

Moraes, H., Aoki, M., Freitas, C., Arruda, A., Drago, G., & Moreira, A. (2017). SIgA response and incidence of upper respiratory tract infections during intensified training in youth basketball players. *Biology of Sport*, *34*(1), 49-55. https://doi.org/10.5114/biolsport.2017.63733

Moreira, A., de Moura, N. R., Coutts, A., Costa, E. C., Kempton, T., & Aoki, M. S. (2013). Monitoring internal training load and mucosal immune responses in futsal athletes. *Journal of Strength and Conditioning Research*, *27*(5), 1253-1259.

Murphy, A. P., Duffield, R., Kellett, A., Gescheit, D., & Reid, M. (2015). The Effect of Predeparture Training Loads on Posttour Physical Capacities in High-Performance Junior Tennis Players. *International Journal of Sports Physiology and Performance*, *10*(8), 986-993. https://doi.org/10.1123/ijspp.2014-0374

Mutch, B. J., & Banister, E. W. (1983). Ammonia metabolism in exercise and fatigue: A review. *Medicine and Science in Sports and Exercise*, *15*(1), 41-50.

Ratel, S. (2018). *Préparation physique du jeune sportif—Le guide scientifique et pratique* (Amphora (Editions)).

Ratel, S., & Blazevich, A. J. (2017). Are Prepubertal Children Metabolically Comparable to Well-Trained Adult Endurance Athletes? *Sports Medicine*, *47*(8), 1477-1485. https://doi.org/10.1007/s40279-016-0671-1

Schmitt, L., Hellard, P., Millet, G. P., Roels, B., Richalet, J. P., & Fouillot, J. P. (2006). Heart rate variability and performance at two different altitudes in well-trained swimmers. *International Journal of Sports Medicine*, *27*(3), 226-231. https://doi.org/10.1055/s-2005-865647

Seiler, K. S., & Kjerland, G. Ø. (2006). Quantifying training intensity distribution in elite endurance athletes: Is there evidence for an "optimal" distribution? *Scandinavian Journal of Medicine & Science in Sports*, *16*(1), 49-56. https://doi.org/10.1111/j.1600-0838.2004.00418.x

Seiler, S. (2010). What is best practice for training intensity and duration distribution in endurance athletes? *International Journal of Sports Physiology and Performance*, *5*(3), 276-291. https://doi.org/10.1123/ijspp.5.3.276

Sempé, M., & Pédron, G. (1971). *Croissance et Maturation Osseuse* (Théraplix).

St Clair Gibson, A., & Noakes, T. (2004). Evidence for complex system integration and dynamic neural regulation of skeletal muscle recruitment during exercise in humans. *British Journal of Sports Medicine*, *38*(6), 797-806. https://doi.org/10.1136/bjsm.2003.009852

Stöggl, T., & Sperlich, B. (2014). Polarized training has greater impact on key endurance variables than threshold, high intensity, or high volume training. *Frontiers in Physiology*, *5*. https://www.frontiersin.org/article/10.3389/fphys.2014.00033

Treff, G., Winkert, K., Sareban, M., Steinacker, J. M., & Sperlich, B. (2019). The Polarization-Index: A Simple Calculation to Distinguish Polarized From Non-polarized Training Intensity Distributions. Frontiers in Physiology, 10.