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Non-Ergodicity and Within-Person Associations Between Enjoyment, Exertion, and Recovery in University Rowers

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Abstract

Understanding how athletes experience and adapt to training requires attention to both psychological and physiological factors. This study investigated the day-to-day relationships between enjoyment, perceived exertion, and perceived recovery in university-level rowers, and whether group-level patterns reflect individual-level processes, an assumption known as ergodicity, which may not hold in dynamic psychological domains like sport. Using a repeated-measures design, 33 athletes provided daily self-reports across a competitive season. Due to varying data completeness and assumption checks across pairs, final analytical samples differed: 12 for enjoyment and perceived exertion, 11 for enjoyment and perceived recovery, and 19 for perceived exertion and perceived recovery. Analyses compared group-level associations, calculated using Pearson correlations and general linear regressions (GLRs), to individual-level associations, assessed using repeated measures correlation (RMCorr), and GLRs performed on each participant's repeated measures. RMCorr revealed a statistically significant, weak negative association between perceived exertion and next-day perceived recovery, with outlier (r_m = -0.10, p = .034). Although only one association was statistically significant, comparisons across all variable pairs revealed discrepancies between group-level and individual-level estimates, as well as substantial variation in individual slopes. These differences in direction and strength suggest that the relationships between enjoyment, perceived exertion, and perceived recovery may not generalize from group to individual-level, aligning with the study's aim of testing non-ergodicity. These findings point to the value of individualized monitoring in applied sport settings. Perceived exertion remains a practical monitoring tool. Future studies should include diverse samples, objective indicators, and non-linear time series methods to capture individual-specific patterns.

Keywords: Perceived exertion; Perceived recovery; Enjoyment; Non-ergodicity; Repeated measures correlation

Non-Ergodicity and Within-Person Associations Between Enjoyment, Exertion, and Recovery in University Rowers

Athletes across all levels and sporting disciplines engage in training and competition with the aim of optimizing their performance, realizing their full potential, and achieving sporting success. To reach these outcomes, they rely on training methods they believe will provide a competitive edge. In response, researchers in the fields of psychology and sport and movement sciences, along with practitioners who apply their findings, have worked to identify the psychological, physiological, and contextual factors that contribute to peak performance, and to translate this knowledge into evidence-based training practices.

Among these factors, psychological variables such as enjoyment, perceived recovery, and perceived exertion have received attention due to their influence on both short-term performance (Csikszentmihalyi, 1990; Kellmann et al., 2018) and long-term athletic development (Kellmann, 2010; Kellmann et al., 2018; Van Yperen et al., 2022). Enjoyment has been linked to reduced perceived exertion (Csikszentmihalyi, 1990) and tentatively to improved psychological recovery, both of which may contribute to enhanced performance outcomes (Reinecke et al., 2011). Understanding how these interrelated constructs function across day-to-day training and competition is essential for optimizing athlete preparation, well-being, and sustained success.

Background

Enjoyment

Enjoyment is widely regarded as an important psychological construct across multiple life domains, including education, work, and sport (Kawabata & Mallett, 2022; Scanlan, Carpenter, Lobel, et al., 1993; Van Yperen et al., 2022). Despite this recognized importance, the literature lacks a universally agreed upon definition of enjoyment (Csikszentmihalyi, 1990; Scanlan, Carpenter, Simons, et al., 1993; Kapsner, 2009; Kawabata & Mallett, 2022).

Kawabata and Mallett (2022) describe this conceptual ambiguity as stemming from debate over whether enjoyment should be understood as an affective state, a subjective experience, a cognitive appraisal, or a combination of these elements. Regardless of a definitive conceptualization, enjoyment has been consistently associated with a range of psychological benefits. It has been linked to enhanced well-being (Mazzucchelli et al., 2010; Siddiquee et al., 2014; Tse et al., 2020) and increased motivation (Deci & Ryan, 1985). Within the framework of Self-Determination Theory (Deci & Ryan, 1985), enjoyment plays a central role in intrinsic motivation, functioning as a key regulatory mechanism. That is, the more an activity is experienced as enjoyable, the more likely an individual is to engage in it voluntarily and consistently over time.

In the sport context, enjoyment can be defined as a positive affective response to sport participation that reflects general feelings of joy (Scanlan et al., 2015). This conceptualization serves as the working definition for the present study. Research highlights its importance for athlete development, performance, and retention (Scanlan, Carpenter, Lobel, et al., 1993; Van Yperen et al., 2022). For instance, Van Yperen et al. (2022) identified enjoyment as the strongest predictor of both short-term (6-month) and long-term (4-year) dropout in youth sport. In this way, enjoyment may act as a key facilitator of commitment and long-term sport engagement. In addition, Lonsdale et al. (2009) found that intrinsic motivation, which is closely tied to enjoyment, was negatively associated with athlete burnout. This suggests that fostering enjoyment may help buffer against burnout. Further supporting this, Puente-Díaz (2011) found that mastery-approach goals enhanced enjoyment, which in turn was associated with greater satisfaction, effort, and performance. Taken together, these findings highlight enjoyment not only as a desirable outcome of sport participation but also as an important factor influencing athletes' motivation, psychological resilience, and sustained engagement.

Moreover, enjoyment may also influence how athletes experience and respond to physical demands during training and competition, specifically through its relationship with exertion.

Exertion

Exertion typically refers to the objective physical and physiological effort an individual exerts during an activity (Hutchinson, 2021). It can be quantified using measures such as heart rate, oxygen consumption (VO_2), blood lactate concentration, or power output. These physiological metrics provide an external, observable indication of how much work the body is performing. In contrast, *perceived* exertion refers to an individual's subjective rating of how demanding an activity felt at a given moment and is commonly operationalized using Borg's session Rating of Perceived Exertion (sRPE) scale, which asks individuals to rate the intensity of their effort based on internal cues such as muscle fatigue, breathing rate, and psychological strain (Borg, 1998). Although originally designed to reflect physiological load, perceived exertion has increasingly been recognized as encompassing both physical and psychological components (Hutchinson, 2021; Eston, 2012; Marcora, 2009).

In sport contexts, perceived exertion plays a role in monitoring athlete load and guiding training adaptations (Céline et al., 2010; Hutchinson, 2021; Ueda & Kurokawa, 1995). Using perceived exertion data to monitor and adjust training load, Céline et al. showed that growth results are comparable to when using heart rate to monitor and adjust load. This demonstrates that when used effectively, perceived exertion monitoring can offer a cost-efficient and practical alternative to physiological monitoring methods in guiding athlete development.

Enjoyment may influence perceived exertion. For example, research on flow states suggests that athletes immersed in enjoyable, optimally challenging tasks often report reduced awareness of physical effort, allowing them to sustain higher intensities for longer durations (Csikszentmihalyi, 1990). Parfitt and Gledhill (2004) similarly found that, at the same objectively measured intensity, participants rated preferred sessions as more enjoyable and less effortful, suggesting that enjoyment may down-regulate perceived exertion. Thus, enjoyment may act as a protective psychological factor, buffering the subjective experience of fatigue and facilitating sustained high-effort engagement, both within sessions and across training cycles.

However, higher enjoyment is not always associated with lower perceived exertion. For instance, Bartlett et al. (2011) found that high-intensity interval running was perceived as more enjoyable than moderate-intensity continuous running, despite eliciting higher RPE scores. While this may appear to contradict the findings of Parfitt and Gledhill (2004), it may reflect the unique appeal of certain high-intensity formats, such as their time efficiency or variety compared to longer, moderate-intensity sessions. Importantly, because exercise intensity differed between conditions, the study cannot speak directly to whether higher enjoyment reduces perceived effort under equivalent exertion. Instead, these findings highlight that enjoyment and exertion can co-occur depending on contextual or individual factors. Taken together, this evidence suggests that while enjoyment is not always associated with lower perceived exertion, it may act as a buffer by reducing perceived exertion when the activity is preferred. Understanding how exertion is perceived during activity is important, but equally essential is athletes' ability to recover between training bouts, which underpins long-term adaptation and performance maintenance.

Recovery

Kellmann et al. (2018) define recovery as a multifaceted process of physical and psychological restoration that unfolds over time in response to fatigue. Fatigue is understood as a state of tiredness arising from internal or external demands, such as intense physical exercise or sustained cognitive effort. Recovery mitigates fatigue by restoring depleted resources through physical regeneration (e.g., sleep, rest) and psychological strategies (e.g., relaxation techniques). Perceived recovery refers to an individual's subjective assessment of how well they have recovered physically and mentally following exertion (Munro & Kenttä & Hassmén, 1998). It encompasses perceptions of muscle soreness, fatigue, energy levels, mental readiness, and general well-being. One widely used instrument to assess this is the Total Quality Recovery (TQR) scale (Kenttä & Hassmén, 1998), which asks athletes to rate their overall recovery on a single-item scale from 6 (very poor recovery) to 20 (very good recovery).

In sport, exertion and recovery are closely intertwined. Athletic development relies on cycles of functional overreaching, where fatigue is deliberately induced through training (i.e. exertion), followed by sufficient recovery to stimulate physiological adaptation and long-term performance gains (Kellmann et al., 2018; Meeusen et al., 2013). When recovery is inadequate, non-functional overreaching can occur, increasing the risk of underrecovery, which in turn may lead to performance decline, accumulated fatigue, and reduced psychological well-being (Kellmann et al., 2018; Meeusen et al., 2013; Kellmann, 2010). These processes highlight the dynamic relationship between exertion and recovery, and demonstrate that fatigue and recovery exist along a continuum influenced by both physical and psychological factors.

Although direct research on the relationship between enjoyment and recovery is limited, there are emerging findings. Reinecke et al. (2011) found that enjoyment of leisure activities, such as entertainment media, contributed to psychological recovery and improved subsequent cognitive performance. In the sport domain, Selmi et al. (2018) observed that athletes' enjoyment during small-sided football games was not influenced by their pre-existing fatigue or recovery status, suggesting that enjoyment may remain stable even in less recovered states. Additionally, van Hooff and De Pater (2017) reported that experiencing pleasure during evening leisure activities was associated with better recovery both that same evening and on the following day. Together, these studies imply that enjoyment may facilitate recovery by counteracting psychological strain.

Dynamics and individual specificity

Athletes' psychological states, such as enjoyment, perceived exertion, and perceived recovery, do not exist in isolation or remain static over time (Kellmann et al., 2018; Den Hartigh et al., 2016). Instead, they form part of a broader dynamic system in which psychological and physiological variables continuously interact, fluctuate, and adapt in response to internal and external demands (Kellmann et al., 2018; Den Hartigh et al., 2016). In dynamic systems, patterns of change emerge over time, and seemingly small fluctuations can accumulate to influence long-term outcomes such as performance, motivation, or well-being (Den Hartigh et al., 2016; Den Hartigh et al., 2022).

To truly understand these dynamic processes, it is necessary to observe them at the level where they unfold, within individuals over time (Neumann et al., 2021). Group-level averages often obscure meaningful fluctuations and interactions that are only detectable within individuals over time (Molenaar, 2004; Fisher et al., 2018; Neumann et al., 2021). This issue, known as the ergodicity problem, reflects the recognized challenge that group-level associations, such as average correlations between enjoyment, exertion, and recovery, should not be assumed to generalize to the processes occurring within individuals (Neumann et al., 2021). In other words, the strength, direction, and temporal patterns of these relationships may differ meaningfully from athlete to athlete, shaped by individual characteristics, training context, or fluctuations over time.

Despite this, most research in sport psychology has relied on cross-sectional or group-level designs, often using a limited number of time points (Neumann, Van Yperen, et al., 2024). Such approaches provide limited insight into the day-to-day dynamics of psychological experiences within athletes, especially across extended periods such as a competitive season (Neumann, Van Yperen, et al., 2024). As a result, the within-person, time-dependent relationships among key sport-relevant psychological factors, such as enjoyment, perceived exertion, and perceived recovery remain poorly understood, particularly in the naturalistic context of ongoing athletic training and competition. Taken together, these insights emphasize the need for research that captures the day-to-day fluctuations of enjoyment, perceived exertion, and recovery within individual athletes over time. Understanding these dynamics at the within-person level can provide more ecologically valid insights into how these psychological factors interact in real-world training environments.

The Present Study

To address the outlined research gaps, this study examined the dynamic, day-to-day relationships between enjoyment, perceived exertion, and recovery within individual athletes over the course of a competitive rowing season. By adopting a within-person, longitudinal design, this research focuses on how these psychological constructs fluctuate and interact over time in the natural context of daily training and competition. Crucially, this design allows for comparisons between group-level associations and individual-level processes, addressing concerns related to the ergodicity problem. In doing so, the study tests not only the overall patterns across the team but also explores whether these patterns generalize to individual athletes or whether meaningful person-specific differences emerge.

Based on the literature outlined, the following hypotheses are proposed:

H1: There is a negative association between enjoyment and perceived exertion; that is, higher enjoyment will be associated with lower perceived exertion.

H2: There is a positive association between enjoyment and perceived recovery; greater enjoyment is expected to predict higher perceived recovery.

H3: There is a negative association between perceived exertion and perceived recovery; that is, higher perceived exertion will be associated with lower perceived recovery.

H4: The strength and direction of these associations will vary depending on the level of analysis; that is, within-person associations are expected to differ from group-level trends, reflecting non-ergodicity.

Methods

Participants

A total of 33 rowers (32 Dutch, 1 international) from an elite Dutch student rowing organization participated in this study. All athletes were students who trained and competed at the university level on a voluntary basis after being selected from an applicant pool by the coaching team at the beginning of the 2024-2025 season, which ran from September 2024 to July 2025. Participants ranged in age from 18 to 25 years (M = 20.61, SD = 1.56). Upon selection, all rowers were informed of the data collection procedures. Participation in the study was voluntary with no monetary or other reward incentive, and written informed consent was obtained from all participants prior to data collection. All rowers consented to the use of their data for research purposes. Throughout the season, athletes completed six training sessions per week, consisting of strength training, endurance exercises, and on-water rowing. Training emphasis shifted from strength-based sessions early in the season to increased boat work as the season progressed. On race weeks, training volume would reduce to three to four days a week. A total of 11 races across 19 race days were completed.

The cohort consisted of 21 men and 12 women split into three teams, divided by gender, weight class, and team size:

- Open Class Men's Team (no weight restrictions): 12 rowers, divided into an eight-person crew and a four-person crew.
- Open Class Women's Team (no weight restrictions): 12 rowers, divided into an eight-person crew and a four-person crew.

- Lightweight Men’s Team: 9 rowers, forming an eight-person crew with one rotating member. Lightweight rowers could not exceed 72.5 kg individually, with a maximum average crew weight of 70 kg.

Due to data privacy regulations, individual-level demographic information such as height, weight, and team membership could not be linked to participants. While the age and gender distributions of the overall cohort are known, they were stored separately from the analytical data and cannot be traced to individuals. Consequently, no demographic breakdowns are reported for specific subsamples. Team-level descriptions are provided to contextualize the cohort’s composition without compromising participant confidentiality.

Procedure

This study received ethical approval from the Ethics Committee of the Faculty of Behavioral and Social Sciences at the University of Groningen (research code: PSY-2122-S-0103). Data were collected as part of the implementation of a daily monitoring system, in collaboration with the University of Groningen, to enable the rowing club to monitor athlete resilience and enhance training design and responsiveness. The monitoring system included daily assessments of perceived exertion, perceived recovery, enjoyment, and other psychological variables, which were used to create individualized profiles for each rower. Prior to each training session, participants received an SMS containing links to two online questionnaires: a pre-training questionnaire and a post-training questionnaire. The pre-training questionnaire included the perceived recovery measure alongside other psychological indicators (e.g., motivation). Upon completing their training, participants used the link provided via SMS to complete the post-training questionnaire, which included measures of perceived exertion, enjoyment, and other psychological variables (e.g., perceived performance). Participants were instructed to complete the post-training questionnaire within 30 minutes of finishing their training session to ensure accurate and timely reporting.

Measures

Single-item self-report measures were used to assess rowers' subjective experiences. Self-reporting was deemed appropriate given the study's aim to capture internal states such as perceived exertion, perceived recovery, and enjoyment, which are inherently subjective and cannot be directly observed or objectively measured. Furthermore, self-reporting has the added benefit of encouraging participants to engage in self-monitoring and reflection, which may enhance awareness of their internal states and support adaptive regulation of training responses. The use of single-item measures is well-supported in sport and exercise contexts, where brevity is essential to minimize participant burden and reduce the risk of attrition (Borg, 1982; Kenttä & Hassmén, 1998; Neumann et al., 2024; Allen et al., 2022). These measures were selected to ensure feasibility for daily, repeated assessments, while aligning with the goal of capturing dynamic, individual-specific processes such as exertion, recovery, and enjoyment, thereby providing meaningful, person-level insights to inform training programs.

Perceived Exertion

Perceived exertion was measured using the session Rating of Perceived Exertion (sRPE) scale, consisting of the single item, "How hard was the training?", translated into Dutch as "Hoe inspannend was deze training?". The sRPE scale, originally developed by Borg (1982), uses a response range from 6 ("very, very light", "heel, heel licht inspannend") to 20 ("very, very hard", "heel, heel inspannend"). This scale is designed to correspond approximately to heart rates ranging from 60 to 200 beats per minute, providing a linear representation of perceived effort. The sRPE was selected in part due to its inclusion in the monitoring system and its compatibility with the response format of the TQR scale (Brink et al., 2010; Neumann, Van Yperen, et al., 2024; Neumann, Brauers, et al., 2024).

Perceived Recovery

Perceived recovery was assessed using the Total Quality Recovery (TQR) scale, consisting of the single item, "How good is your recovery?", translated as "Hoe goed ben je hersteld?". Responses were provided on a scale ranging from 6 ("very, very poor recovery", "heel, heel slecht hersteld") to 20 ("very, very good recovery", "heel, heel goed hersteld"). The TQR is a widely used tool for monitoring recovery status in athletic populations and was incorporated as part of the monitoring system (Kenttä & Hassmén, 1998; Brink et al., 2010; Neumann, Van Yperen, et al., 2024; Neumann, Brauers, et al., 2024).

Perceived Enjoyment

Perceived enjoyment was measured with a single-item scale based on existing questionnaire items that have been tailored to the current context (Neumann, Van Yperen, et al., 2024; Puente-Díaz, 2011; Van Yperen et al., 2022) consisting of the question, "How much did you enjoy the training session(s) today?", translated into Dutch as "Hoe leuk vond je de training(en) vandaag?". Responses were provided using a visual analogue scale (VAS) ranging from 0 ("not at all", "helemaal niet leuk") to 100 ("very much", "heel erg leuk"). To facilitate comparison across variables, enjoyment scores originally on a 0-100 scale, were linearly transformed to match the 6-20 scale used for perceived exertion and perceived recovery.

Data Preprocessing

The dataset initially consisted of 33 rowers from three different teams, with a total of 2,809 observations collected across the rowing season at time of analysis. To ensure data quality, consistency, and compliance with the assumptions of repeated measures correlation (RMCorr; Bakdash & Marusich, 2017), several exclusion criteria were applied. For each variable pair of interest, only observations where both relevant values were recorded were retained for analysis. Missing values were handled on a pairwise basis, meaning data points were excluded only if one or both variables in the pair were missing. Imputation was not performed to avoid introducing assumptions into the dataset. Second, for analyses involving perceived recovery, a next-session perceived recovery variable was created, using the next valid training session's perceived recovery value, to compare with the current day's perceived exertion and enjoyment. Observations were excluded if the next valid training session occurred more than one day later, ensuring temporal proximity between variables.

Finally, participants were required to meet a minimum response threshold to be included in the final analysis. Specifically, only rowers who completed at least 70% of all questionnaire prompts and provided a minimum of 10 valid observations after applying the above criteria were retained. This threshold was implemented to ensure sufficient within-person data density for reliable estimation of individual slopes and to minimize the influence of incomplete or inconsistent data on the repeated measures correlation analyses. A 70% response rate is consistent with recommendations in longitudinal and diary research, where lower compliance rates have been shown to compromise the validity, reliability, and representativeness of within-person estimates (Stone & Shiffman, 2002). Moreover, repeated measures techniques such as RMCorr require an adequate number of observations per participant to ensure stable within-person estimates, and sparse or inconsistent data can substantially reduce the reliability and interpretability of such models (Bakdash & Marusich, 2017).

After applying exclusion criteria for each pairwise comparison, the following final samples were obtained:

- Perceived Recovery and Perceived Exertion: 12 rowers (M = 41.08 observations per rower; SD = 6.92 observations per rower; range = 30 to 54; total observations = 493)
- Perceived Recovery and Enjoyment: 12 rowers (M = 41.08 observations per rower; SD = 6.92 observations per rower; range = 30 to 54; total observations = 493)

- Perceived Exertion and Enjoyment: 24 rowers (M = 71.20 observations per rower; SD = 16.82 observations per rower; range = 46 to 101; total observations = 1709)

Data Analysis

Each pairwise combination of variables was analyzed using RMCorr (Bakdash & Marusich, 2017) to examine within-individual associations between perceived recovery, perceived exertion, and enjoyment across the rowing season. RMCorr was designed to assess linear relationships between paired variables while accounting for the dependence of repeated observations within individuals. It provided a single correlation coefficient (r_m) that reflected the consistent within-person association across all participants while controlling for between-person variability. RMCorr achieves this by modelling a shared slope and correlation coefficient, while allowing for participant-specific intercepts. This approach represents a methodological midpoint between traditional group-level correlations and fully individual analyses. While it does not estimate unique slopes for each individual, it improves upon conventional group-level methods by preserving the repeated-measures structure and isolating within-person covariance. As such, it was well suited to the time-series data and the study's focus on within-person processes. RMCorr also directly addresses concerns raised by the ergodicity problem (Molenaar, 2004; Fisher et al., 2018; Neumann et al., 2021), which highlights the limitations of generalizing group-level findings to individual-level processes. RMCorr was applied to each variable pair.

To evaluate the ergodicity of the observed relationships, two complementary analyses were conducted alongside the RMCorr approach. First, group-level between-person associations were calculated using Pearson correlation coefficients and general linear regressions (GLRs), based on the mean of each participant's repeated measures. This produced group-level statistics in which everyone was represented by a single data point, thereby eliminating all within-person variability. Second, individual-level regressions were performed using each participant's repeated observations to estimate unique within-person slopes. These two approaches provided a contrast to RMCorr. Like the between-person method, RMCorr produced a shared single correlation coefficient and slope. However, unlike the between-person analysis, which requires averaging across repeated measures, RMCorr leverages the repeated-measures data by modeling within-person associations and assigning each participant their own intercept to account for differences in baseline levels. At the same time, unlike the individual-level regressions, RMCorr constrained the slope to be identical across participants, thereby sacrificing some individual-level variation in favor of estimating a shared within-person trend. Taken together, these comparisons enabled a structured assessment of ergodicity across three analytical levels: group-level between-person (Pearson r, GLR), shared within-person controlling for between-person (RMCorr), and fully within-person (individual regressions).

Assumptions of linearity and normality across all analyses were visually assessed using scatterplots and residual plots for each participant. Violations were identified in two of the three pairwise analyses, affecting a subset of participants, who were excluded from the corresponding models to maintain the validity of the model estimates. Based on the individual-level regressions described above, slope outliers, defined as individual slopes exceeding ±2 standard deviations from the shared RMCorr slope, were identified in two of the three analyses. Sensitivity checks involved re-running the analyses with these outliers excluded to assess their impact on the results. To further assess the robustness of the findings, both standard and bootstrapped RMCorr analyses were conducted for each pair of variables. Bootstrapping involved resampling the dataset 1,000 times to create simulated samples. This procedure generated confidence intervals based on the variability in the observed data, and provided a more reliable estimate of the stability of the results, particularly when normality assumptions might not have held.

Three separate RMCorr analyses were conducted, corresponding to the study's first three hypotheses (H1-H3): (1) the association between perceived exertion and next-session perceived recovery; (2) the association between enjoyment and perceived exertion; and (3) the association between enjoyment and next-session perceived recovery. In line with the fourth hypothesis (H4), group-level between-person Pearson correlations and GLR slopes, as well as individual-level within-person regression slopes, were compared against the shared within-person RMCorr estimates from H1-H3 to evaluate ergodicity. These comparisons focused on differences in correlation strength and slope direction across the three analytical levels. To support this comparison, the proportion of individual slopes from the participant-level regressions that ran in the opposite direction to the RMCorr slope was calculated as a descriptive indicator of non-ergodicity. All analyses were conducted in R (R Core Team, 2024) using RStudio (Posit Team, 2024) and the RMCorr package (Bakdash & Marusich, 2017).

Results

Variable Pair Associations

For each variable pair, both standard and bootstrapped (1,000 resamples) RMCorr analyses were conducted, producing consistent r_m and p-values with minimal deviations in the 95% confidence intervals (see Table 1). Of the three pairs, only perceived exertion and perceived recovery (H3) showed a statistically significant association (r_m = -0.101, 95% CI [-0.192, -0.007], p = .034), displaying a trivial to weak negative relationship, with higher perceived exertion scores associated with lower perceived recovery scores. No statistically significant associations were found between enjoyment and perceived exertion (H1) (r_m = -0.034, 95% CI [-0.089, 0.021], p = .226), or between enjoyment and perceived recovery (H2) (r_m = 0.010, 95% CI [-0.079, 0.100], p = .820).

Sensitivity analyses were conducted to assess the influence of slope outliers on the RMCorr results (see Table 1). After excluding an identified opposite-direction slope outlier from the enjoyment and perceived exertion pair (H1), the within-person association strengthened (r_m = -0.053, 95% CI [-0.110, 0.003], p = .064), compared to the initial analysis (r_m = -0.034, 95% CI [-0.089, 0.021], p = .226). However, the result remained non-significant. Similarly, removal of an opposite slope outlier from the perceived exertion and perceived recovery pair (H3) resulted in a stronger, statistically significant negative association (r_m = -0.165, 95% CI [-0.259, -0.069], $p < .001$), relative to the initial analysis (r_m = -0.101, 95% CI [-0.192, -0.007], p = .034). This means that higher perceived exertion scores were associated with even lower perceived recovery scores after outlier removal. The bootstrapped and standard CIs remained consistent, indicating greater stability of the effect estimate.

Table 1

Repeated Measures Correlation (RMCorr), Bootstrapped, and Between-Person Results for Each Variable Pair

Variable Pair	n	r_m	95% CI	p	Bootstrapped 95% CI	Opposite Slopes
(H1) Enjoyment - Exertion	19	-0.034	[-0.089, 0.021]	0.226	[-0.095, 0.032]	7/19 (36.8%)
(H1) Enjoyment - Exertion (Outliers removed)	18	-0.053	[-0.110, 0.003]	0.064	[-0.113, 0.006]	6/18 (33.3%)
(H2) Enjoyment - Recovery	12	0.01	[-0.079, 0.100]	0.82	[-0.077, 0.097]	6/12 (50%)
(H3) Exertion - Recovery	11	-0.101	[-0.192, -0.007]	0.034	[-0.196, -0.001]	1/11 (9.1%)
(H3) Exertion - Recovery (Outliers Removed)	10	-0.165	[-0.259, -0.069]	<0.001	[-0.267, -0.054]	0/10 (0%)

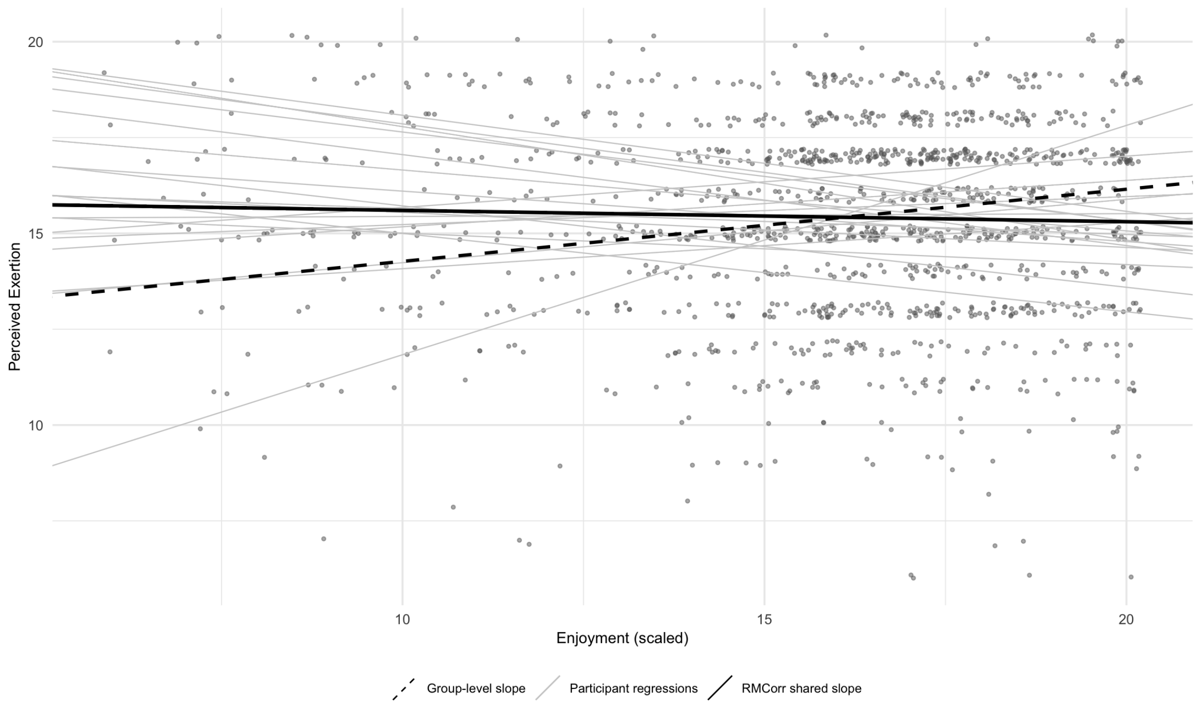
Note. r_m= repeated measures correlation; 95% CI = 95% confidence interval; Opposite slopes reflect the number and percentage of participants whose individual regression slopes opposed the direction of the shared RMCorr slope. Bootstrapped results are based on 1,000 resamples.

Ergodicity Comparisons

To assess ergodicity, specifically whether within-person associations differ from group-level trends (H4), additional analyses were conducted across multiple analytical levels. Upon conducting individual-level GLRs for the enjoyment and perceived exertion pairing (Figure 1), 7 of 19 participants (36.8%) had slopes opposing the direction of the shared within-person RMCorr slope. Over a third of participants exhibited an opposite valence relationship for this variable pair compared to the shared RMCorr estimate. Although not statistically significant, the group-level between-person Pearson correlation and GLR, based on participant-level averages, showed a weak positive association ($r = 0.259$, $p = .284$) with a slope of 0.188. In contrast, the shared within-person RMCorr analysis yielded a trivial, non-significant negative association ($r_m = -0.034$, 95% CI [-0.089, 0.021], $p = .226$), with a slope of -0.030. These results reflect a divergence in direction and strength between the group-level between-person and shared within-person estimates.

Figure 1

Scatterplot of Enjoyment and Perceived Exertion with Within- and Between-Person Lines



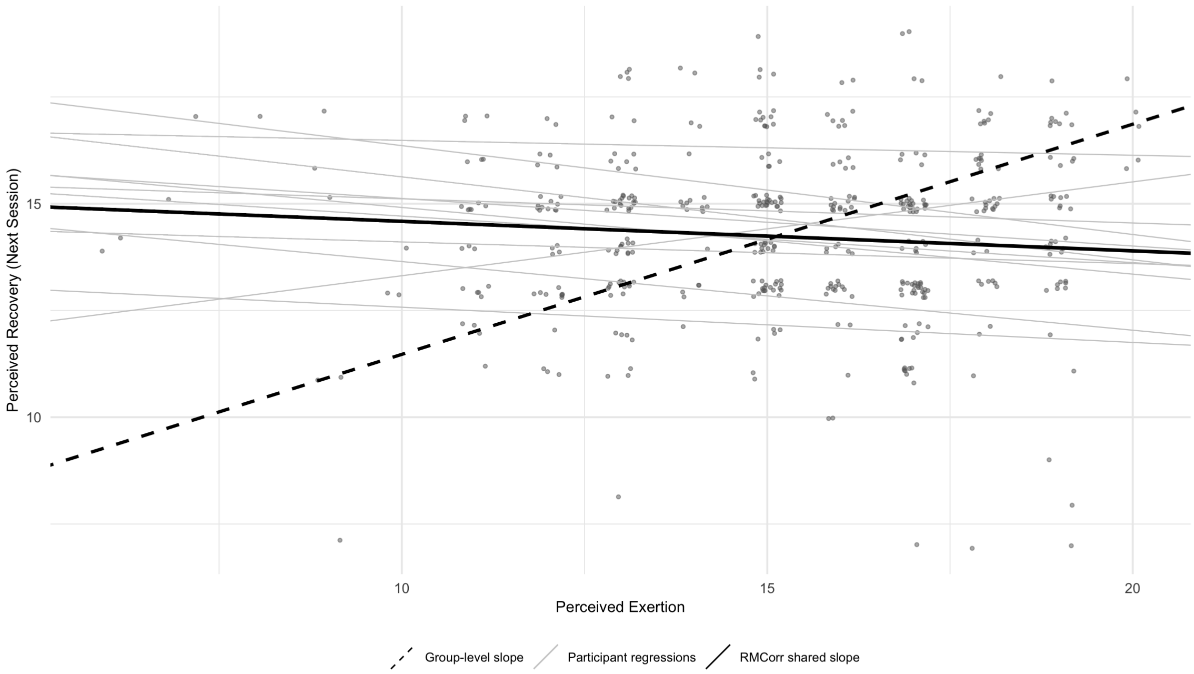
Note. Jittered raw data points reflect all observations across participants. Dashed black line represents the group-level between-person general linear regression (GLR) based on participant-level averages. Solid black line depicts the shared slope from the repeated measures correlation (RMCorr) analysis. Solid grey lines represent individual regression lines.

Upon conducting individual-level GLRs for the perceived exertion and perceived recovery pairing (Figure 2), 1 of 11 participants (9.1%) had slopes opposing the direction of the shared within-person RMCorr slope. One participant had an opposite valence relationship for the pair compared to the shared RMCorr estimate. While not statistically significant, the group-level between-person Pearson correlation and GLR, based on participant-level averages, displayed a moderate positive association ($r = 0.525$, $p = .097$), with a slope of

0.539. In contrast, the shared within-person RMCorr showed a statistically significant trivial to weak negative association (r_m = -0.101, 95% CI [-0.192, -0.007], p = .034), with a shared slope of -0.069. These results reflect a divergence in direction and strength between the group-level between-person and shared within-person estimates.

Figure 2

Scatterplot of Perceived Exertion and Perceived Recovery with Within- and Between-Person Lines

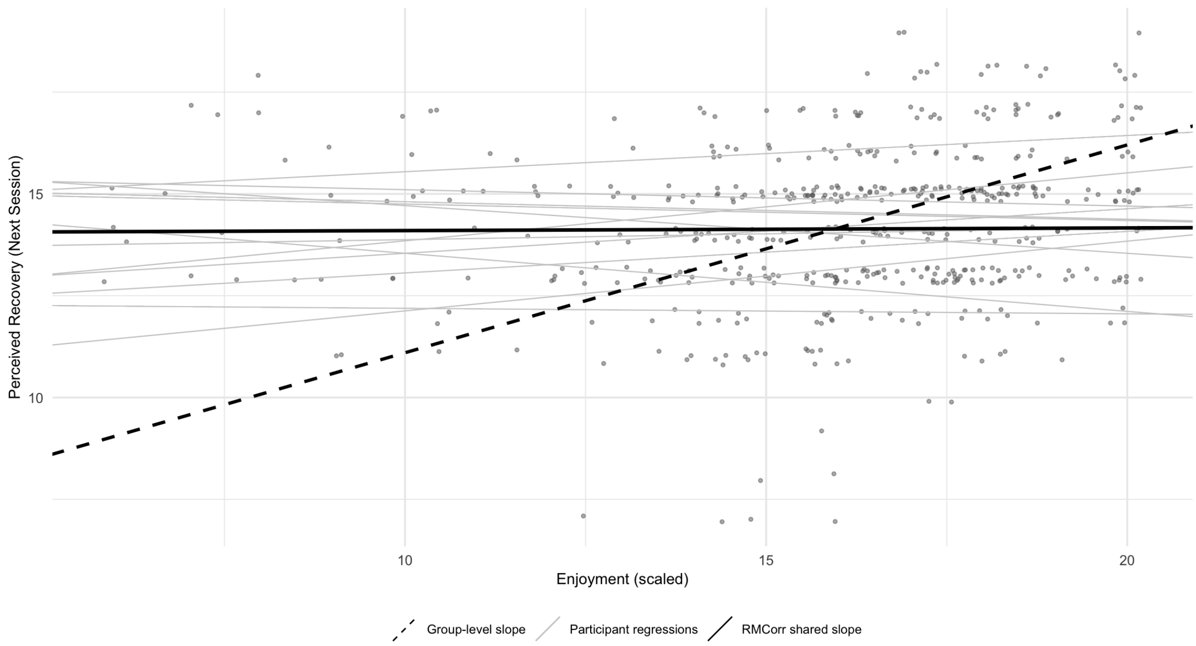


Note. Jittered raw data points reflect all observations across participants. Dashed black line represents the group-level between-person general linear regression (GLR) based on participant-level averages. Solid black line depicts the shared slope from the repeated measures correlation (RMCorr) analysis. Solid grey lines represent individual regression lines.

Upon conducting individual-level GLRs for the enjoyment and perceived recovery pairing (Figure 3), 6 of 12 participants (50%) had slopes opposing the direction of the shared within-person RMCorr slope. Half of the participants had an opposite valence relationship for the pair compared to the shared RMCorr estimate. Although not statistically significant, the group-level between-person Pearson correlation and GLR, based on participant-level averages, displayed a moderate positive association ($r = 0.575$, $p = .050$), with a slope of 0.510. However, the shared within-person RMCorr displayed a trivial, not statistically significant association ($r_m = 0.010$, 95% CI [-0.079, 0.100], $p = .820$), with a shared slope of 0.007. These results reflect a divergence in strength between the group-level between-person and shared within-person estimates.

Figure 3

Scatterplot of Enjoyment and Perceived Recovery with Within- and Between-Person Lines

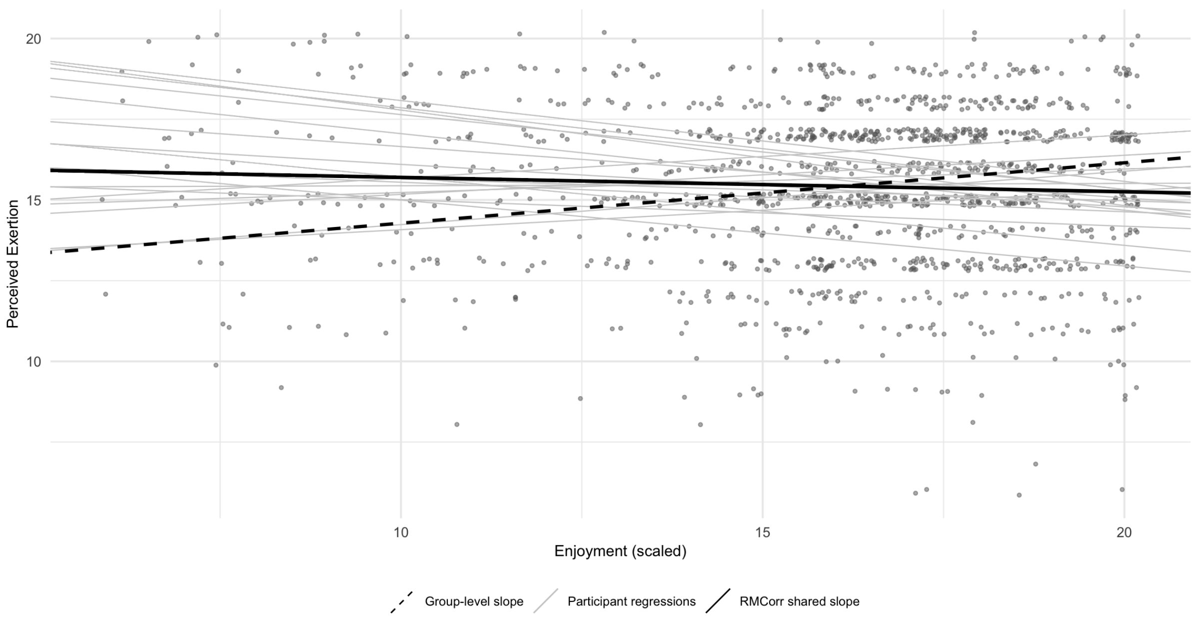


Note. Jittered raw data points reflect all observations across participants. Dashed black line represents the group-level between-person general linear regression (GLR) based on participant-level averages. Solid black line depicts the shared slope from the repeated measures correlation (RMCorr) analysis. Solid grey lines represent individual regression lines.

Following the removal of slope outliers, the proportion of participants whose individual slopes opposed the shared RMC slope were recalculated and between-person analyses were repeated. The enjoyment and perceived exertion pair (Figure 4) had a new proportion of 6 of 18 participants (33.3%) that had slopes opposing the direction of the shared within-person RMC slope. This reflects one fewer participant with an opposing slope than in the initial RMCorr analysis. The new group-level between-person Pearson correlation and GLR, based on participant-level averages, remained not statistically significant and indicated a weak positive association ($r = 0.257$, $p = .303$), with a slope of 0.187. In contrast to the shared within-person RMCorr which revealed a weak, not statistically significant negative association (r_m = -0.053, 95% CI [-0.110, 0.003], p = .064), with a shared slope of -0.045.

Figure 4

Scatterplot of Enjoyment and Perceived Exertion (Outliers Removed) with Within- and Between-Person Lines



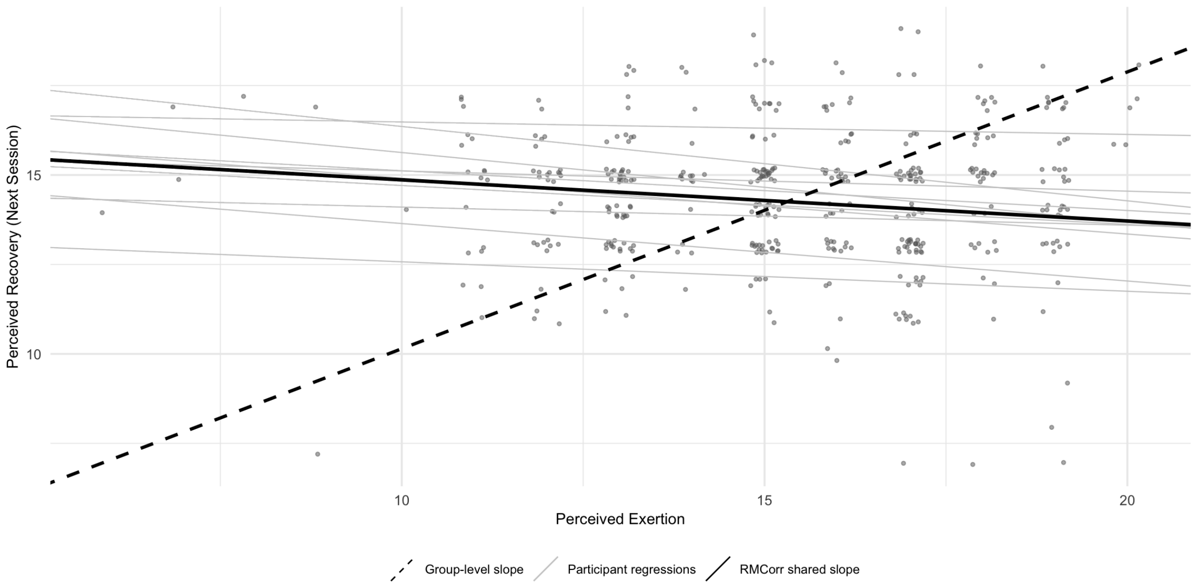
Note. Jittered raw data points reflect all observations across participants after removing the slope outlier participant. Dashed black line represents the group-level between-person general linear regression (GLR) based on participant-level averages. Solid black line depicts the shared slope from the repeated measures correlation (RMCorr) analysis. Solid grey lines represent individual regression lines.

The perceived exertion and perceived recovery pair (Figure 5) had a new proportion of 0 of 10 participants (0%) that had slopes opposing the direction of the shared within-person RMC slope. This means all participants had the same valence relationship for the pair as the overall RMCorr after the outlier removal. The new group-level between-person

Pearson correlation and GLR, based on participant-level averages, displayed a strong positive association ($r = 0.607$, $p = .063$), with a GLR slope of 0.774. This contrasted the within-person RMCorr which showed a statistically significant weak negative association that became stronger after outlier removal ($r_m = -0.165$, 95% CI [-0.259, -0.069], $p < .001$), with a shared slope of -0.115. In both pairings, the direction of the group-level between-person Pearson correlations and GLR slopes remained different from the shared within-person RMCorr results, consistent with H4, as observed in the initial analyses (see Figures 4–5).

Figure 5

Scatterplot of Perceived Exertion and Perceived Recovery (Outliers Removed) with Within- and Between-Person Lines



Note. Jittered raw data points reflect all observations across participants after removing the slope outlier participant. Dashed black line represents the group-level between-person general linear regression (GLR) based on participant-level averages. Solid black line depicts the shared slope from the repeated measures correlation (RMCorr) analysis. Solid grey lines represent individual regression lines.

Discussion

The present study aimed to examine the relationships between enjoyment, perceived exertion, and perceived recovery, as well as the ergodicity of these relationships within a sample of university-level rowing athletes. It was hypothesized that higher enjoyment would be related to lower perceived exertion (H1) and higher perceived recovery (H2), while higher perceived exertion would be related to lower perceived recovery (H3). Additionally, it was expected that these relationships would differ across analytical levels (H4): group-level between-person, shared within-person, and individual-level within-person, in line with literature highlighting the potential for non-ergodic patterns in psychological processes (Neumann et al., 2021). The findings provided partial support for these expectations, with evidence of a negative relationship between exertion and recovery, alongside notable ergodic discrepancies across levels of analysis.

Consistent with current literature (Céline et al., 2010; Hutchinson, 2021; Kellmann et al., 2018), rowers who reported higher levels of perceived exertion also reported lower perceived recovery the following day. These findings align with theoretical frameworks describing recovery as a dynamic continuum between fatigue and restoration, whereby exertion temporarily increases fatigue, followed by recovery processes that facilitate adaptation and performance improvements (Kellmann et al., 2018). A sensitivity analysis was conducted after identifying an outlier to assess the robustness of the relationship between perceived exertion and recovery. The analysis revealed that the strength of the negative relationship between perceived exertion and next-day perceived recovery was trivial to weak when the outlier remained in the dataset. Upon removal of the outlier, the relationship increased in strength, although it remained weak. While this suggests that the outlier may have attenuated the observable relationship between these variables, the weak strength of the relationship overall was not anticipated, particularly given theoretical expectations of a more pronounced relationship between exertion, fatigue, and subsequent recovery (Kellmann et al., 2018; Meeusen et al., 2013; Kellmann, 2010).

One possible explanation for the weaker-than-expected negative relationship relates to socially desirable responding (Podsakoff et al., 2003). Participants may have exaggerated both their perceived exertion, to appear more hardworking, and their perceived recovery, to avoid seeming poorly conditioned or insufficiently recovered. Such response patterns could obscure the expected negative relationship between these variables. This interpretation is further supported by the identified outlier, whose responses reflected a moderate positive relationship between exertion and recovery, a pattern inconsistent with theoretical models describing the exertion-recovery dynamic (Kellmann et al., 2018). Nonetheless, the current findings suggest that while perceived exertion contributes to next-day perceived recovery, other factors likely play a role in shaping recovery outcomes. These may include individual recovery management strategies (e.g., sleep quality, nutritional practices) (Kellmann et al., 2018), as well as unmeasured confounders such as psychological stress, academic demands, or additional physical activity undertaken between training sessions. Future studies should aim to control for these variables to better isolate the contribution of perceived exertion to perceived recovery.

Beyond the evidence for the relationship between perceived exertion and recovery, other results suggested the presence of non-ergodicity across the relationships examined. In line with previous research on non-ergodic patterns in sport and psychological processes (Neumann et al., 2021), the findings revealed notable discrepancies between shared within-person and group-level between-person relationships. Although not statistically significant, the group-level between-person analysis, which does not account for how these constructs relate within individuals, indicated a positive relationship between perceived exertion and recovery, directly contrasting the negative relationship observed in the shared within-person

RMCorr analysis. A similar divergence emerged for the enjoyment and perceived exertion pair, where the direction of the relationship reversed across analytical levels. For enjoyment and recovery, the group-level between-person relationship was substantially stronger than the almost zero relationship at the shared within-person. While not statistically significant, across all three variable pairs, the group-level between-person findings consistently reflected stronger and more positive relationships than those estimated by shared within-person RMCorr. This suggests there may be meaningful differences in how these constructs relate depending on the level of analysis, though further investigation is required.

Additionally, considerable heterogeneity was observed in the individual slopes for both enjoyment-related relationships. While RMCorr accounts for within-person variation, unlike the between-person analyses, it still produces a shared summary that can obscure meaningful individual differences (Bakdash & Marusich, 2017). A substantial proportion of participants showed individual relationships opposite in valence to the RMCorr relationship for both enjoyment and perceived exertion, as well as enjoyment and perceived recovery, suggesting considerable variability in how individuals experience and report these relationships. Together with the observed discrepancies between within-person and between-person analyses across all three variable pairs, these patterns suggest potential non-ergodicity in the data. However, since only one of the RMCorr analyses reached statistical significance, while all other analyses did not, these findings should be interpreted with caution. While not conclusive, they are consistent with theoretical perspectives (Molenaar, 2004; Fisher et al., 2018; Neumann et al., 2021) arguing that group-level findings may not accurately reflect individual-level processes, reinforcing the value of considering individual variability in sport psychology research.

While we found evidence for the proposed relationship between perceived exertion and perceived recovery, the hypothesized relationships involving enjoyment were not supported by the present data. Previous literature has tentatively suggested that enjoyment may support recovery (Reinecke et al., 2011; van Hooff & De Pater, 2017) and influence perceptions of exertion through positive affective experiences (Csikszentmihalyi, 1990). However, the current findings did not provide evidence to either support or refute these proposed associations. One possible explanation lies in the conceptual ambiguity surrounding enjoyment in research. Enjoyment has been variously defined as an affective state, subjective experience, cognitive appraisal, or mood (Kawabata & Mallett, 2022). Kawabata and Mallett (2022) noted, some scholars argue that while distinctions between pleasure and enjoyment may be theoretically meaningful, they may not reflect how athletes interpret these experiences in practice. If participants based their enjoyment ratings on immediate, pleasurable aspects of training rather than broader feelings of joy (Scanlan et al., 2015), this may have weakened its relationships with exertion and recovery. Additionally, mood may have confounded these ratings. In this study, mood was assessed prior to training alongside perceived recovery. Athletes entering training in a positive or negative mood may have evaluated the session's enjoyment accordingly, regardless of the session itself. These mood-based effects may have masked potential relationships between enjoyment and the other constructs. Taken together, both conceptual and methodological factors may have contributed to the null findings regarding enjoyment, highlighting the need for greater clarity and tighter control in future research.

Furthermore, previous studies support the suggestion that the relationships between enjoyment, perceived exertion, and perceived recovery may be context dependent. For example, as noted earlier, Selmi et al. (2018) found that athletes' enjoyment remained stable despite varying levels of fatigue and recovery status, indicating that enjoyment and recovery may operate independently under certain conditions. A similar context-dependent relationship may exist between enjoyment and perceived exertion. While positive experiences, including enjoyment, often accompany flow states, and flow during sport participation may lead to reduced conscious awareness of exertion, this effect depends on factors such as the balance between skill and challenge (Csikszentmihalyi, 1990). It is therefore reasonable to suggest that, in some cases, athletes may perceive high exertion as enjoyable if it reflects meaningful challenge and aligns with their skill level. This idea aligns with findings reported by Bartlett et al. (2011), also noted earlier, who observed that athletes rated high-intensity interval running as more enjoyable than moderate-intensity continuous exercise, despite its greater physical demands. In contrast, excessive fatigue resulting from exertion, or a mismatch between skill and challenge, may prevent flow and hinder enjoyment. Such variability could dilute observable relationships at the group level and may help explain the heterogeneity observed in individual slopes within the current study.

A final consideration relates again to the timing of measurements. In this study, while enjoyment was measured directly after training, perceived recovery was assessed the day following training. Although this approach is necessary to allow sufficient time for the recovery process to unfold, it also introduces potential for unmeasured confounding factors. As mentioned previously in relation to the association between perceived exertion and perceived recovery, factors such as sleep quality, nutritional intake, or stress levels during the intervening period may have influenced perceived recovery, potentially masking any contribution from enjoyment.

Strengths and Limitations

This study demonstrates several methodological and conceptual strengths that contribute to the validity of the findings. Firstly, the sample was drawn from a single university rowing club, which, while limiting generalizability, ensured that participants shared a similar training environment, coaching structure, and club culture. This consistency reduces variability stemming from external factors and allows for a more controlled examination of the relationships between enjoyment, perceived exertion, and perceived recovery. Additionally, the dataset was relatively rich in terms of repeated measures collected across multiple training sessions rather than a lab setting. This repeated-measures approach provided insight into within-person variability and allowed for the application of statistical techniques such as RMCorr, which accounts for individual-level patterns. Such analyses increase the ecological validity of the findings, offering a more nuanced understanding of how psychological and perceptual factors fluctuate within athletes across real-world training environments.

Another conceptual strength of the study is its consideration of non-ergodicity within psychological processes. By applying a design that distinguishes and compares shared within-person and group-level between-person associations, the study addressed the possibility that group-level statistics may not generalize to individuals. The novel approach of comparing the shared RMCorr slope to each rower's own within-person regression slopes further enabled a nuanced exploration of variability in psychological responses, contributing to sport psychology research that challenges traditional group-level interpretations (Molenaar, 2004; Fisher et al., 2018; Neumann et al., 2021). By examining relationships at three levels: (1) the group level, capturing how the relationships trend across the rowers, (2) the shared within-individual level, summarizing the relationship trends observed within each rower over time into a single estimate, and (3) the individual level, capturing each rower's unique relationship based on their own day-to-day fluctuations, the study provided a clearer and more structured view of how enjoyment, exertion, and recovery relate in applied sport contexts.

Despite these strengths, several limitations should be acknowledged. The study relied exclusively on self-reported measures of enjoyment, perceived exertion, and perceived recovery. While self-report tools are widely used in sport psychology due to their feasibility and the single-item measures used have relatively good validity (Borg, 1982; Kenttä &

Hassmén, 1998; Neumann et al., 2024; Allen et al., 2022), they are inherently vulnerable to biases such as socially desirable responding and subjective interpretation of scale items (Podsakoff et al., 2003). This means that participants may have unintentionally over or under-reported their experiences in ways that did not accurately reflect their true psychological or physical states. These reporting distortions could have affected the observed relationships between variables, and without concurrent objective measures, it is not possible to verify or correct for this potential inaccuracy.

In addition, concerns emerged due to the number of participant exclusions based on response rates. A relatively large proportion of the original sample was excluded to ensure both adequate response rates and enough observations per individual. While this approach was methodologically necessary to maintain the reliability of the analyses, it may have introduced selection bias, favoring participants with higher levels of training adherence, motivation, or engagement with the psychological monitoring process. Consequently, this may have resulted in range restriction, reducing variability in psychological responses across the overall sample and potentially limiting the strength or detectability of associations between enjoyment, exertion, and recovery. Moreover, in the between-person analyses, participant-level means were based on differing numbers of observations, which may have introduced slight imbalances in how consistently each rower's average reflected their underlying responses. Nonetheless, the presence of mixed individual slopes observed in this study suggests that meaningful variability may still exist at the individual level, even within a relatively homogenous participant group.

Finally, two strengths of the study also present important limitations. While the sampling strategy supported internal consistency; it limits generalizability. Data were collected from a single university rowing club, which helped reduce external variability by ensuring participants shared a similar training environment and team culture. However, it also restricts the extent to which findings can be applied to athletes from different sports, competitive levels, or training environments. Additionally, the uneven gender distribution and lack of detailed demographic information for the final analytical samples further constrain the generalizability of the results. Moreover, while the comparison between group-level between-person and shared within-individual results offers insight into potential non-ergodicity, the analytic structures were not fully symmetrical. Pearson and GLR analyses were based on participant-level averages, whereas RMCorr incorporated full time series data. This methodological mismatch may limit the interpretability of differences across levels and should be acknowledged when drawing conclusions. These limitations highlight the need for caution in interpretation and offer direction for more robust designs in future investigations.

Recommendations for Future Research and Practical Implications

The present findings offer some practical implications for applied sport settings. Although the association between perceived exertion and next-day perceived recovery was weak, perceived exertion remains a low-cost, accessible tool for monitoring how athletes experience training demands and subsequent recovery. Given the considerable individual variability observed in psychological responses, practitioners should exercise caution when interpreting group-level trends and instead consider individualized monitoring approaches that account for athlete-specific patterns in exertion, enjoyment, and recovery.

Future research should seek to replicate these findings across different sports, clubs, and more diverse samples to enhance external validity and better understand how these psychological processes operate across varied sporting environments. Multi-club or multi-sport studies using consistent data collection systems would allow for stronger generalizability and help identify potential sport-specific or contextual influences. Additionally, to address the limitations of self-report measures, future studies could incorporate objective physiological indicators, such as heart rate, heart rate variability, or wearable technology to complement psychological monitoring. This may provide a more comprehensive understanding of the relationship between perceived and physiological recovery and exertion by capturing physiological responses that may not align with self-reports and are less prone to social desirability bias (Ciuk et al., 2015; Lima et al., 2012). Researchers should also consider controlling for mood, as baseline affective states may influence subjective ratings of enjoyment, exertion, and recovery (Brose et al., 2013).

Finally, studies could explore, with greater resolution, how individual-specific relationships between these constructs evolve over time by applying non-linear time series analysis methods, which extend beyond the static association estimates provided by RMCorr. One such method is vector autoregressive (VAR) modelling, which captures how multiple psychological variables influence each other across time points and allows for modelling individual-level dynamics using each athlete's time series data (Bringmann et al., 2013). Future research could also adopt more symmetrical analytical approaches than those used in this study, such as those described by Neumann et al. (2021), which involve comparing group-level daily statistics (means, SDs, correlations) averaged across time with corresponding individual-level time series statistics averaged across individuals. This approach offers a more rigorous test of ergodicity by ensuring that both levels are derived from temporally structured data in a comparable format. However, it depends on participants being measured on the same days, which may be difficult to achieve in applied sport contexts with variable compliance and missing data. Incorporating such techniques may yield deeper insights into the temporal interplay between enjoyment, exertion, and recovery in sport.

Conclusion

In summary, the present study provides preliminary insight into the relationships between enjoyment, perceived exertion, and perceived recovery within a university rowing context, while also highlighting the relevance of non-ergodicity in interpreting psychological processes in sport. Although findings partially supported the proposed associations, considerable individual variability, and lack of evidence to support relationships involving enjoyment emphasize the complexity of these constructs. The results reinforce the utility of perceived exertion as a practical monitoring tool, while also underscoring the importance of individual-level monitoring rather than relying on group-level trends.

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