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Correlation between sports burnout and unforced errors in competition among high school table tennis players

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Abstract. Purpose: To explore the relationship between athlete burnout and unforced errors among high school table tennis players. Methods: Fifteen players completed the 12-item Athlete Burnout Questionnaire (ABQ), and one singles match video for each player was coded. Spearman correlations, permutation tests, and Holm correction were used. Results: The mean unforced error rate was 20.25 ± 6.60 per 100 rallies. Emotional and physical exhaustion was positively correlated with the error rate (r_s = 0.641, adjusted p = 0.037), whereas the correlation coefficients for reduced sense of accomplishment and sport devaluation were 0.499 and 0.446, respectively, both non-significant. Emotional and physical exhaustion was positively correlated with the out-of-bounds error rate, and reduced sense of accomplishment was positively correlated with the net error rate (adjusted p = 0.035 for both). Conclusion: The association between emotional and physical exhaustion and the unforced error rate in competition received statistical support, whereas the associations of the other dimensions remain unclear.

Keywords: high school students, table tennis, athlete burnout, unforced errors, correlation analysis

1. Introduction

Table tennis competition requires players to complete information judgement, movement adjustment, and stroke control under continuously changing incoming ball conditions. Errors in competition may arise from the technical pressure exerted by the opponent, but may also occur under relatively controllable hitting conditions. The latter type of error is usually termed an unforced error; its analytical value lies in reflecting players' technical stability when reasonable return conditions are available, rather than attributing all lost points to insufficient individual ability. For high school players who simultaneously undertake academic and training tasks, training recovery, competition pressure, and psychological state should be jointly addressed in training management. Domestic studies on athlete burnout, competition anxiety, coach support, and psychological resources indicate that athlete burnout is jointly influenced by the individual and the training environment [1-8]; recent longitudinal reviews have also emphasised its multidimensional and dynamic characteristics [9].

Athlete burnout is a multidimensional psychological state associated with training and competition experiences. Recent psychometric studies of the ABQ have divided it into three dimensions, namely emotional and physical exhaustion, reduced sense of accomplishment, and sport devaluation, and support the examination of scale structure and measurement invariance across ages and sport types [10]. Validation studies

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of the simplified Chinese version of the ABQ further confirmed the applicability of the 12-item structure among Chinese collegiate and elite athletes [11]. Domestic studies often use "exercise-induced mental fatigue" to describe comparable persistent burnout experiences [12, 13]; however, acute mental fatigue induced by short-term cognitive tasks and the persistent state measured by the ABQ are not the same concept. This study uniformly designates the core variable as "athlete burnout" so as to avoid conflating persistent psychological states, immediate cognitive fatigue, and physiological fatigue in interpretation.

Domestic studies of table tennis and badminton have found that sport experience, attentional state, and sport-specific information processing are related to reaction speed, decision accuracy, and movement performance [14, 15]; a systematic review of racket sports also showed that mental fatigue induced by cognitive tasks may reduce hitting speed, accuracy, and visuomotor response performance [16]. These studies mainly examined sport-specific cognitive processing or the acute state after short-term cognitive load, whereas the present study focuses on the relationship between persistent athlete burnout and unforced errors in competition. Existing evidence for the simplified Chinese version of the ABQ comes mainly from collegiate and elite athletes, and its applicability among Chinese high school table tennis players still requires cautious interpretation in light of the present sample [10, 11]. Therefore, this study specifies the scale version, competition exposure, and error judgement rules simultaneously.

Based on the above issues, this study analyses the relationships between the three dimensions of athlete burnout and the unforced error rate in competition, and further examines whether the results are consistent when error counts and rally-standardised error rates are used, as well as whether the associations differ across error types. The analysis reports correlation coefficients, confidence intervals, and significance test results in an integrated manner.

2. Research subjects and methods

2.1. Research subjects

This study included 15 enrolled high school students who had at least one year of systematic table tennis training, participated in school team training, and possessed singles competition experience. Each player completed one ABQ measurement and was paired with one eligible singles match video. The individual player served as the unit of statistical analysis, and no comparisons were made by sex or grade.

Inclusion criteria were as follows: the ability to understand and independently complete the questionnaire; match videos that fully presented valid rallies; and the absence of acute sports injuries affecting normal participation. Exclusion criteria included obviously invalid questionnaire responses, missing key match footage, and inability to confirm the correspondence between the questionnaire and the match video. Only one eligible match per player was included, so as to avoid treating multiple matches of the same person as independent samples.

2.2. Research methods

2.2.1. Literature review method

Literature on athlete burnout, mental fatigue, adolescent athletes, and table tennis performance was retrieved through journal official websites, public records of literature databases, and university institutional repositories. The literature mainly covered Chinese empirical studies, scale validation studies, systematic reviews, and longitudinal studies published between 2022 and 2025; domestic athlete studies served as the primary contextual basis, while English literature supplemented psychometric and international research

advances. Studies of different age groups and sport-specific populations were used for theoretical comparison and did not directly substitute for measurement evidence from high school table tennis players.

2.2.2. Questionnaire measurement and variable setting

The ABQ was used to assess athlete burnout, which constitutes a measurement content different from immediate reaction speed or acute cognitive fatigue. This study adopted the 12-item structure of the simplified Chinese version, in which emotional and physical exhaustion, reduced sense of accomplishment, and sport devaluation contain 5, 3, and 4 items, respectively. Items were scored from 1 to 5, and dimension scores were the mean of the constituent items, with higher scores indicating more frequent corresponding burnout experiences. Given that existing evidence for the Chinese version comes mainly from collegiate and elite athletes, the dimension scores of the high school sample were interpreted with caution in conjunction with the internal consistency results.

The three dimensions respectively reflect emotional and physical exhaustion, reduced sense of sport accomplishment, and negative evaluation of the value of sport participation. Recent psychometric studies support the use of the ABQ as a multidimensional instrument and suggest that the applicability of total or dimension scores may vary with sample characteristics. Therefore, this study used the three dimensions as the main indicators of analysis and additionally computed the equally weighted mean of the three dimension means as a supplementary description. Scores of each dimension were treated as continuous variables, and no burnout grades were assigned.

2.2.3. Match video coding scheme and error judgement

The match videos included in the analysis fully presented the serve, receive, rally, and rally-ending processes, and allowed identification of the incoming ball placement, player movement, and stroke outcome. A process that produced a valid point was counted as one rally; repeated playback of the same rally did not increase the count, and the number of strokes within a rally was not used as the denominator. Rallies with a re-serve, points awarded by decision, and rallies in which technical outcomes could not be observed were recorded separately.

An unforced error was operationally defined as a technical error that directly ended a rally owing to the player's own execution deviation, when the speed, spin, and placement of the incoming ball did not create evident uncontrollable pressure and the player had a reasonable opportunity to reach the position and complete the intended stroke. Judgement should comprehensively consider the difficulty of the incoming ball, the degree of movement restriction, the hitting position, and the completion of the movement, rather than relying solely on the final landing point of the ball. Errors under the opponent's forceful attack, extreme placement, or evident loss of balance were in principle regarded as forced errors; rallies that were difficult to judge were classified as "undetermined" and could not be forcibly assigned to unforced errors.

After an error had been identified as unforced, it was further classified by outcome into three types, namely net errors, out-of-bounds errors, and missed hits. A net error refers to an error in which the ball did not cross the net after being struck, or touched the net and did not land on the opponent's court; an out-of-bounds error refers to a stroke that crossed the net but whose first bounce did not land on the opponent's court; a missed hit refers to ending a rally without striking the ball despite a reasonable opportunity to do so. Legal returns such as edge balls were not counted as out-of-bounds errors, legal serves that touched the net and were re-served were not counted as net errors, and at most one unforced error of the target player was recorded per rally. The above classification served as the unified coding rule of this study.

The match videos were independently judged by two uniformly trained coders, who did not view the players' ABQ scores during coding. Before formal coding, independent clips were used to unify the judgement rules; coding disagreements were reviewed rally by rally, and the final judgement after review served as the basis for statistics.

2.2.4. Indicator calculation and data processing

The main performance indicator was the unforced error rate, calculated as: unforced error rate = total number of unforced errors ÷ total number of valid rallies in the match × 100, expressed in errors per 100 rallies. The rates of net errors, out-of-bounds errors, and missed hits used the same number of rallies as the denominator.

Proportional composition of error types = number of unforced errors of a given type ÷ total number of unforced errors × 100. This indicator describes the internal composition of errors and is not equivalent to the incidence of that error type across all match rallies. When the total number of unforced errors was 0, the proportional composition was treated as a missing value rather than replaced by 0.

Questionnaires and match videos were paired one-to-one by player code. Questionnaire data were used to calculate the three dimension scores according to the ABQ scoring rules; video data were summarised by valid rallies, total unforced errors, and the three outcome categories of net errors, out-of-bounds errors, and missed hits. After pairing, analytical data were formed for 15 players, each of whom corresponded to one set of ABQ dimension scores and one set of match statistics.

All statistics were computed from the paired data of the same group of 15 players. Item value ranges, numbers of valid rallies, total error counts, and type counts were checked item by item, so as to ensure that the sum of the three error types equalled the total number of unforced errors and that the number of errors did not exceed the total number of valid rallies. There were no missing values in the data, and no post hoc adjustment of individual scores was performed.

2.2.5. Mathematical statistics

Before the analysis, the relationships between the three ABQ dimensions and the unforced error rate were specified as the primary question. Continuous summary indicators were described using mean ± standard deviation, and the median and the first and third quartiles were also reported; item scores were treated as ordinal data. After checking value boundaries, zero counts, and scatterplots, Spearman's rank correlation coefficient (r_s) was used to describe monotonic associations, without presupposing a normal distribution. p values were estimated through 20,000 random permutations, using two-sided tests and including the original arrangement; the 95% confidence intervals of the correlation coefficients were calculated using 10,000 nonparametric bootstrap resamples with the athlete record as the unit.

The primary tests of the three dimensions were treated as one test family, and p values were corrected using the Holm method, with a statistical significance level of 0.05. The correlation analysis of error counts served as a supplementary analysis, with Holm correction applied separately to its three tests; the nine tests of the three dimensions with the three error types were separately corrected as an exploratory test family. The overall dimension mean was used to supplement the description of the overall direction. Results report correlation coefficients, 95% confidence intervals, and p values simultaneously, and the correlation coefficients were compared by their numerical characteristics.

Python with NumPy and pandas was used for data processing, rank computation, permutation testing, and statistical summarisation, with versions NumPy 2.3.5 and pandas 2.2.3. The 15 players constituted the analytical sample size, whereas match rallies and questionnaire items were not counted as independent sample size, so as to avoid pseudo-replication [17]. Given the small sample size, this study did not build multivariate regression models or conduct grade or sex subgroup tests.

3. Results and analysis

3.1. Scores on each dimension of sports burnout

Table 1. Descriptive statistics of burnout dimension scores (n = 15)

Indicator	Mean ± SD	Median (Q1, Q3)	Range
Emotional and physical exhaustion	2.95 ± 0.69	3.20 (2.60, 3.30)	1.40–4.00
Reduced sense of accomplishment	2.82 ± 0.62	3.00 (2.33, 3.33)	1.67–3.67
Sport devaluation	2.60 ± 0.80	2.50 (2.00, 3.25)	1.25–3.75
Overall dimension mean	2.79 ± 0.55	2.84 (2.56, 3.02)	1.66–3.74

Note: Dimension scores ranged from 1 to 5; Q1 and Q3 are the 25th and 75th percentiles, respectively; the overall dimension mean is the equally weighted mean of the three dimension means.

As shown in Table 1, the scores for emotional and physical exhaustion, reduced sense of accomplishment, and sport devaluation were (2.95 ± 0.69), (2.82 ± 0.62), and (2.60 ± 0.80), respectively, and the overall dimension mean was (2.79 ± 0.55). In terms of means, emotional and physical exhaustion scored the highest and sport devaluation the lowest. The Cronbach's α coefficients of the three dimensions were 0.778, 0.545, and 0.807, respectively.

3.2. Unforced errors in competition and their type distribution

Table 2. Descriptive statistics of unforced errors in competition (n = 15)

Indicator	Errors per match, mean ± SD	Errors per 100 rallies, mean ± SD	Overall proportion (%)
Net errors	8.87 ± 3.27	9.44 ± 3.34	46.67
Out-of-bounds errors	7.87 ± 3.93	8.36 ± 3.99	41.40
Missed hits	2.27 ± 1.94	2.45 ± 2.23	11.93
Total unforced errors	19.00 ± 6.58	20.25 ± 6.60	100.00

Note: Proportions were calculated from the aggregate count of all 285 unforced errors.

As shown in Table 2, the match videos of the 15 players contained a total of 1,420 valid rallies and 285 unforced errors; the number of unforced errors per match ranged from 8 to 31, and the mean individual unforced error rate was (20.25 ± 6.60) per 100 rallies. There were 133 net errors (46.67%), 118 out-of-bounds errors (41.40%), and 34 missed hits (11.93%). Net errors and out-of-bounds errors together accounted for 88.07% of all unforced errors.

3.3. Correlation between athlete burnout and the unforced error rate

Table 3. Correlation analysis of burnout dimensions with the unforced error rate (n = 15)

Dimension	r_s	95% CI	Adjusted p
Emotional and physical exhaustion	0.641	0.085 to 0.947	0.037
Reduced sense of accomplishment	0.499	0.085 to 0.774	0.123
Sport devaluation	0.446	-0.086 to 0.814	0.123

Note: r_s is Spearman's rank correlation coefficient; p values were obtained from two-sided permutation tests and corrected by the Holm method; 95% confidence intervals were calculated by the bootstrap method.

As shown in Table 3, the correlation coefficients between the three athlete burnout dimensions and the unforced error rate were all positive. Among them, emotional and physical exhaustion was significantly positively correlated with the unforced error rate (r_s = 0.641, p = 0.037), whereas the correlation coefficients of reduced sense of accomplishment and sport devaluation with the unforced error rate were 0.499 and 0.446, respectively, neither reaching statistical significance (p = 0.123).

3.4. Correlations between athlete burnout and different error types

Table 4. Correlation analysis of burnout dimensions with each error type rate

Dimension	Net errors	Out-of-bounds errors	Missed hits
Emotional and physical exhaustion	0.648 (0.076)	0.718 (0.035)	-0.406 (0.600)
Reduced sense of accomplishment	0.697 (0.035)	0.587 (0.141)	-0.419 (0.600)
Sport devaluation	0.341 (0.600)	0.356 (0.600)	0.130 (0.635)

Note: Values in cells are r_s, and values in parentheses are Holm-adjusted p values; the denominator of each error type rate is the total number of valid rallies in the corresponding match of the player.

As shown in Table 4, emotional and physical exhaustion was significantly positively correlated with the out-of-bounds error rate (r_s = 0.718, p = 0.035), and reduced sense of accomplishment was significantly positively correlated with the net error rate (r_s = 0.697, p = 0.035); the remaining correlations did not reach statistical significance.

4. Discussion and conclusion

4.1. Interpretation of the association between athlete burnout and unforced errors in competition

The relationships between burnout dimensions and match error indicators vary with the measurement content and the computational denominator. Emotional and physical exhaustion was positively correlated with the rally-standardised error rate; when the total number of errors was used as the indicator, this association did not reach statistical significance after correction. Calculating the error rate by rallies reflects the frequency of errors per unit of competition exposure more directly, and therefore this study used it as the main performance indicator. Meanwhile, domestic studies have examined athletes' burnout experiences, psychological states, and developmental adjustment from perspectives such as competition anxiety, basic psychological needs, coach support, psychological resilience, and social support. International longitudinal studies and systematic reviews also suggest that the training environment, coaching behaviours, and basic psychological needs may influence changes in athlete burnout [18-20]. High school players' academic schedules, sleep recovery, recent injuries, skill levels, and opponents' abilities may also simultaneously affect questionnaire scores and match errors. Future studies may incorporate these factors into repeated-measures or multivariate analyses so as to further explain the relationship between athlete burnout and competition performance.

4.2. Differences among burnout dimensions and measurement boundaries

The correlation coefficient between emotional and physical exhaustion and the unforced error rate was relatively high, suggesting that this dimension may be more closely related to technical stability in

competition. Emotional and physical exhaustion in the ABQ reflects athletes' subjective experience of resource depletion and is not equivalent to objective physical fitness indicators, whereas reduced sense of accomplishment and sport devaluation reflect self-evaluation and attitudes towards sport to a greater extent [10, 11]. Domestic studies on athlete burnout, mind wandering, and sport-specific decision-making suggest that attentional control may be an important direction for observing the link between subjective burnout experiences and sport performance [1, 14]. Future studies may combine indicators such as training load, muscle fatigue, and attentional control to test the specific links between these dimensions and competition performance.

Domestic studies show that coach support, coach–athlete attachment, satisfaction of basic psychological needs, sport motivation, and psychological resilience are closely related to athlete burnout [2, 4, 5]; foreign longitudinal studies also suggest that coaching behaviours and basic psychological needs may affect changes in burnout over the course of a season [19, 20]. This evidence helps to understand the training environment in which different burnout experiences occur. Future work may further examine the pathways through which basic psychological needs and coach support act on the burnout–error relationship among high school table tennis players.

The α coefficient of the reduced sense of accomplishment dimension was 0.545, relatively low among the three dimensions. The number of items, sample size, and response distribution may all affect the α coefficient. Recent psychometric studies of the ABQ emphasise that scale quality should be comprehensively evaluated in terms of factor structure, internal consistency, and measurement invariance. Therefore, the results for this dimension require cautious interpretation and should continue to be tested in larger samples of high school students.

4.3. Scope of application of the unforced error indicator

The number of unforced errors is intuitive, but differences in match length alter the number of error opportunities to which players are exposed. Therefore, using errors per 100 rallies as the main indicator helps to distinguish "making more errors" from "making errors more frequently per unit of match rallies". However, the number of rallies is only an approximate indicator of competition exposure: the average number of strokes per rally, the proportion of attacking play, and technical difficulty may still differ across matches, and the same rally does not imply an equal number of hitting opportunities. Formal studies should consider further standardisation by valid hitting opportunities according to video availability, and should explain the rationale for the choice of denominator.

Net errors, out-of-bounds errors, and missed hits constitute a classification of error outcomes. Net errors may involve stroke timing, arc control, or misjudgement of spin; out-of-bounds errors may involve racket face angle, stroke force, or placement control; missed hits may involve movement, judgement, or movement sequencing. These possible explanations provide directions for subsequent technical analysis and can be verified in conjunction with kinematic, eye-tracking, or attentional task indicators.

Domestic studies of table tennis and badminton indicate that sport-specific information processing, attentional state, and sport experience are related to reaction speed and decision-making performance [14, 15]; a systematic review of racket sports further pointed out that acute mental fatigue may affect hitting performance and visuomotor reaction time [16]. Such experiments reflect performance changes after short-term cognitive load, whereas the ABQ dimensions reflect more persistent athlete burnout experiences. The two types of evidence cannot directly substitute for each other, but together they suggest that future studies should separately examine the effects of acute states and long-term psychological burden on table tennis technical performance.

4.4. Implications for the management of high school table tennis training

Domestic studies have incorporated coach–athlete attachment, coach autonomy support, basic psychological needs, sport motivation, and psychological resilience into explanatory frameworks of athlete burnout, and international longitudinal studies also support attention to coaching behaviours and within-season changes. For high school table tennis teams, questionnaire status and match errors can serve as parallel observational information for tracking status changes and assisting training arrangements. Continuous individual records help identify changes better than single cross-sectional comparisons, and coaches should make judgements in light of players' previous levels, recent recovery, and actual competition conditions.

Domestic studies suggest that perfectionism, coach support, social support, and self-control are related to athletes' burnout experiences, attentional states, or developmental decisions; international reviews also show that the associations of related factors are not entirely consistent across dimensions and populations [9, 21]. Support for high school athletes should take account of academic work, sleep recovery, and sport-specific training arrangements, and should provide feedback through adjustable process goals, avoiding attributing competition errors simply to willpower or ability.

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