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Effects of Mental Training and Cognitive-Motor-Based Life Kinetik Training on Attention and Concentration Performance in Volleyball Players: A Behavioral and Neurofeedback-Task Assessment

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Abstract

The purpose of this study was to examine the effects of mental training and cognitive-motor-based life kinetik interventions on attention and concentration performance in volleyball players, using the d2 Attention Test as the primary behavioral outcome and an attention-contingent neurofeedback task (NeuroSky MindWave Mobile 2, Brainwave Visualizer barrel-bursting task) as a supplementary, exploratory index. A quasi-experimental, non-randomized pretest-posttest design was employed, using purposive sampling. A total of 66 volleyball players aged 14-16 years were assigned to a mental training group (n=22), a life kinetik group (n=22), and a control group (n=22) that continued routine volleyball training only. Measurements were taken at pretest, posttest (Week 8), Week 12, and Week 16, and analyzed with a 3×4 mixed-design ANOVA. Both intervention groups showed significant, sustained improvements in attention and concentration relative to Control (all Group×Time interactions $p<.001$). The two intervention groups did not differ significantly from one another on either d2 outcome at any post-intervention time point; the only significant direct contrast between them (neurofeedback-task Barrel Count) favored mental training. Gains were largely maintained through the 16-week follow-up, with a partial decline evident between posttest and follow-up. These findings indicate that both mental training and life kinetik training improve attention and concentration performance in volleyball players relative to standard training alone, without evidence that either intervention is superior to the other.

Keywords: Attention, cognitive-motor training, neurofeedback, life kinetik, volleyball

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INTRODUCTION

Modern sports performance cannot be explained solely by physical, technical, and tactical characteristics; cognitive processes such as attention, decision-making, working memory, and executive functions also affect athletic performance. Particularly in open-skill sports, athletes' ability to rapidly perceive environmental stimuli, process information efficiently, and generate appropriate motor responses within a short period is critical for optimal performance. Studies examining the relationship between sports expertise and cognitive performance have demonstrated that athletes exhibit superior attention, processing speed, and executive functions compared with non-athletes (Voss et al., 2010). Furthermore, expert athletes have been reported to possess more advanced perceptual-cognitive skills in tasks requiring attention (Memmert et al., 2009). Accordingly, increasing attention has been directed toward the relationship between cognitive performance and athletic performance in sports science, and intervention programs designed to enhance cognitive performance have received growing research interest (Brimmell et al., 2024).

Volleyball is an open-skill sport that requires rapid decision-making, visual attention, reaction speed, and cognitive flexibility under constantly changing game conditions. During actions such as serve reception, block timing, and defensive organization, athletes are required to rapidly analyze environmental stimuli and produce appropriate motor responses. Reactive agility and perceptual-cognitive determinants have been shown to differ by sex and playing role in competitive young volleyball players (Zwierko et al., 2023). Studies investigating the effects of open-skill sports on cognitive functions have shown that participation in these sports positively influences attention, inhibitory control, and cognitive flexibility (Gu et al., 2019; Heilmann et al., 2022). In addition, the perceptual-cognitive expertise approach suggests that elite athletes are more effective in processing environmental information and allocating attentional resources efficiently (Williams & Ericsson, 2005). Therefore, attention and perceptual-cognitive processes are considered fundamental determinants of performance in volleyball.

The importance of attention and executive functions in sports performance has increasingly been investigated within the framework of the perceptual-cognitive skill training approach. This approach emphasizes that attentional control, anticipation, visual search behavior, and decision-making are essential components of elite performance (Broadbent et al., 2015). Moreover, perceptual-cognitive skill training has been suggested to transfer positively to on-field performance (Romeas et al., 2016). Interventions designed to improve attention performance in athletes may also enhance executive functions and cognitive control processes (Mao et al., 2024). These findings indicate that cognitive performance is not merely a natural consequence of sports participation but a modifiable capacity that can be enhanced through appropriate interventions.

One of the approaches used to improve cognitive performance is mental training. Mental training comprises systematic practices aimed at enhancing attentional control, imagery, concentration, and cognitive awareness. According to mental simulation theory, motor imagery and mental practice share common neural mechanisms with those activated during actual motor performance (Munzert et al., 2009). In addition, motor imagery has been

reported to facilitate both motor learning and cognitive performance in athletes (Lotze & Halsband, 2006). Contemporary research in sport psychology also indicates that mental training may positively influence attentional control, cognitive regulation, and performance optimization (Vealey, 2024). Therefore, mental training is considered an effective approach for improving attention and concentration performance in athletes.

In recent years, cognitive-motor dual-task training has emerged as a prominent intervention model in sports science. This approach requires individuals to perform cognitive and motor tasks simultaneously, thereby enhancing cognitive-motor integration processes. Cognitive-motor training models have been suggested to support cognitive reserve and promote neurocognitive adaptation (Herold et al., 2018; Lucia et al., 2023; Wu et al., 2024). Within this framework, the life kinetik approach has gained attention as a cognitive-motor intervention integrating coordination, attentional control, cognitive processing, and motor adaptation. During life kinetik training, individuals simultaneously perform tasks requiring coordination, reaction, attention, and visual processing. Simultaneous execution of cognitive and motor tasks has been reported to improve attentional control and executive functions (Herold et al., 2018). Furthermore, perceptual-cognitive training has been suggested to transfer positively to sport-specific performance (Broadbent et al., 2015). Nevertheless, studies investigating life kinetik-based interventions in sport-specific populations remain limited. In particular, experimental studies examining the effects of life kinetik interventions on attention and concentration in volleyball players are scarce.

The use of electroencephalography (EEG)-based measurements to assess cognitive performance in athletes has become increasingly widespread in recent years. EEG is a non-invasive method that provides neurophysiological indicators of attention, working memory, decision-making, and cognitive processing. EEG-based and MEG-based studies have linked neural oscillations to attentional processes and the regulation of cognitive states (Lopes da Silva, 2013). Recent studies examining EEG-based assessments in athletes have shown that expert athletes exhibit superior cognitive performance during attention tasks and develop sport-specific neurophysiological adaptations across different sports disciplines (Cheng et al., 2024; Delgado et al., 2025).

A review of the existing literature indicates a growing number of studies investigating the effects of mental training and cognitive-motor interventions on attention and cognitive performance. However, research examining life kinetik-based interventions in sport-specific populations remains limited. In addition, experimental studies directly comparing the effects of mental training and life kinetik interventions are scarce. The limited number of studies evaluating athletes' attention performance using both behavioral attention tests and neurofeedback-based measures represents a gap in the literature. Moreover, studies investigating the retention of intervention effects after the intervention period ends are also limited. In particular, the scarcity of longitudinal experimental studies evaluating attention and concentration performance together with a supplementary neurofeedback-based measure in volleyball players motivates the present study.

The aim of this study was to examine the effects of mental training and life kinetik interventions on attention and concentration performance in volleyball players, using the d2

Attention Test as the primary behavioral outcome and an attention-contingent neurofeedback task as a supplementary, exploratory measure. In addition, follow-up assessments were conducted after the intervention period ended, to determine the persistence of the intervention effects. Based on this aim, the following research hypotheses were formulated:

H_1: Mental training and life kinetik interventions will produce significant changes in attention and concentration performance among volleyball players, relative to a routine-training control group.

H_2: The effects of mental training and life kinetik interventions on attention and concentration performance will differ from each other.

H_3: Changes in attention and concentration performance following the intervention will differ during the follow-up period after the intervention ends.

H_4: Changes observed in behavioral measures of attention and concentration will show a broadly parallel pattern with those observed on the supplementary neurofeedback-task measures.

METHOD

Research Model

This study used a quasi-experimental, non-randomized pretest-posttest design with two intervention groups and one control group (Creswell & Creswell, 2017). Group allocation was not randomized; participants were assigned by purposive sampling, as described below. Posttest measurements were conducted following the eight-week intervention period, with follow-up assessments at Weeks 12 and 16 of the study (i.e., 4 and 8 weeks after the intervention ended) to evaluate the retention of intervention effects after their cessation.

Research Group

The study sample consisted of 66 volleyball players, aged 14-16 years, who regularly participated in volleyball training in Çorum, Türkiye. Of the participants, 40 were female and 26 were male. Participants were assigned to a mental training group (n=22), a life kinetik group (n=22), and a control group (n=22) using purposive sampling. All 66 participants completed all four assessment occasions; there was no attrition.

Table 1 reports age and sex distribution by group. Groups did not differ significantly in age (one-way ANOVA, p=.554) or sex distribution (χ^2, p=.776). Training-experience and weekly training-volume data were not recorded at the individual level for this cohort and could not be added retrospectively; this is noted as a limitation.

Table 1. Baseline age and sex distribution by group

Group	Total	Female	Male	Age
	n (%)	n (%)	n (%)	$\bar{X}$ ± SD
Mental Training	22 (100%)	14 (63.6%)	8 (36.4%)	15.00±.62
Life Kinetik	22 (100%)	12 (54.5%)	10 (45.5%)	14.77±.75
Control	22 (100%)	14 (63.6%)	8 (36.4%)	14.86±.71

Note: χ^2(sex) p=.776; one-way ANOVA (age) p=.554.

An a priori power analysis (Faul et al., 2009) using an assumed effect of f=.40, α=.05, and power=.80 indicated a minimum of 22 participants per group. The complete set of G*Power input parameters (targeted effect, number of measurements, assumed correlation among repeated measures, sphericity correction, and anticipated attrition) is not available to us in full and could not be reconstructed without risk of misstatement; this is noted in the Limitations.

Data Collection Tools

d2 Attention Test: The d2 Attention Test (Brickenkamp & Zillmer, 1998) was used to assess selective attention and concentration. Çağlar and Koruç (2006) reported satisfactory reliability and validity of the d2 in Turkish athletes; the same study also reported a significant practice effect across repeated administrations at 15-day, 30-day, and 90-day intervals. Because the present design administered the d2 on four occasions, this practice effect is a plausible contributor to some of the improvement observed, particularly in the Control group (see Discussion). Total Performance (TN-E) and Concentration Performance (CP) scores were used in the analyses.

Attention-Contingent Neurofeedback Task (NeuroSky MindWave Mobile 2): Neurophysiological measurements were obtained using the NeuroSky MindWave Mobile 2, (NeuroSky Inc., 2022), a single-channel, dry-electrode EEG headset that records frontal-lobe electrical activity and derives a proprietary eSense™ Attention index. Rather than recording this raw eSense value directly, task performance was obtained through the ‘‘barrel-bursting’’ mini-game included in NeuroSky’s Brainwave Visualizer software, in which the headset’s real-time eSense Attention signal controls the bursting of an on-screen barrel: sustained attentional engagement bursts the barrel more quickly, after which a new barrel appears and the timer resets. Participants were seated in a quiet environment free from distracting stimuli and instructed to focus on a fixed point on the volleyball they were holding for a two-minute session.

Two indices were extracted: (1) NeuroSky Best Time, the fastest single barrel-burst time (seconds) achieved in the session, with lower values interpreted as faster attentional engagement, consistent with the protocol used in Beşler (2020); and (2) NeuroSky Barrel Count, the total number of barrels burst within the session, interpreted as an index of sustained concentration.

These indices should not be equated with the raw eSense Attention meter or with any spectral (band-power) EEG measure. They are game-performance outputs gated by the device’s proprietary, non-disclosed attention-detection algorithm, and their psychometric properties have not been independently established in adolescent or athletic populations. NeuroSky’s own technical support documentation (NeuroSky Inc., 2018) describes the Brainwave Visualizer mini-games as illustrative rather than measurement-grade, and recommends its NeuroView Research Tools application for applications requiring accurate, unadjusted brainwave data. Session-level signal-quality metrics and a formal test-retest reliability estimate for this task are not available for this sample; this is addressed further in the Limitations.

Rationale for a Dual-Measure Design. The d2 Attention Test was selected as the primary outcome measure precisely because consumer-grade, single-channel EEG applications such as this one are not equivalent, in measurement precision or independent psychometric validation, to standardized neuropsychological instruments. This limitation was anticipated at the design stage; the neurofeedback task was included as a supplementary, exploratory index intended to complement, not substitute for, the d2 Attention Test's established reliability and validity, rather than as an independently validated neurophysiological outcome. Conclusions regarding intervention efficacy are accordingly anchored primarily in the d2 findings, with the neurofeedback-task indices interpreted as convergent, hypothesis-generating evidence.

Mental Training Protocol: The mental training program targeted attentional control, concentration, imagery, emotional regulation, mindfulness, and cognitive focus, delivered daily for eight weeks (approximately 56 sessions, 5-20 minutes each depending on content).

Life Kinetik Training Protocol: The life kinetik program targeted attentional processes, visual tracking, coordination, motor planning, and cognitive flexibility through cognitive-motor exercises, delivered twice weekly (Wednesdays and Fridays) for eight weeks (16 sessions total).

The two protocols therefore differ by roughly a factor of three in session count, and mean session duration and individual attendance/adherence were not recorded for either group. This dose asymmetry means that any direct efficacy comparison between the two interventions is confounded with total contact time and is addressed as a limitation; we do not rank the two interventions against each other in the results or discussion.

Data Analysis

All statistical analyses were performed using IBM SPSS Statistics (version 22.0). Descriptive statistics are presented as $\bar{X}\pm SD$. Shapiro-Wilk tests were used to assess normality, and Levene's test was used to assess homogeneity of variance. A mixed-design analysis of variance (3 groups×4 time points) was conducted for each dependent variable, with participant specified as the repeated-measures factor. Box's M test was used to assess homogeneity of covariance matrices, and Mauchly's test of sphericity was applied to the within-subject factor; Greenhouse-Geisser-corrected degrees of freedom and p-values are reported wherever sphericity was violated, which was the case for all four outcome variables. Where significant interaction effects were found, Bonferroni-corrected pairwise comparisons were used for both within-subject and between-subject contrasts. Effect sizes were reported as partial eta squared (partial η^2) for the mixed ANOVA and as Hedges' g (Cohen, 1988; Lakens, 2013) for within-group pre-post contrasts, calculated using the average-variance standardizer with the pre-post correlation incorporated and the small-sample correction applied. Between-group difference-in-change contrasts (independent-samples comparison of Post-Pre change scores, with 95% confidence intervals) were additionally computed to evaluate relative intervention efficacy, independent of within-group standardized effect sizes. Partial η^2 values were interpreted as small (.01), medium (.06), and large (.14) per Cohen (1988).

A linear Discriminant Function Analysis (DFA) was performed using Python (scikit-learn; Pedregosa et al., 2011) to examine whether post-test scores on the four outcome measures could discriminate among the three groups. Classification performance was evaluated using leave-one-out cross-validation (LOOCV), with the model refit at each iteration using only the training partition. Statistical significance was set at $p<.05$ for all analyses.

FINDINGS

Table 2. Descriptive statistics ($\bar{X}$±SD) across groups and time points

Group	Time	d2 Attention	d2 CP	NeuroSky Best Time (s)	NeuroSky Barrel Count
Control	Pre	491.77±64.36	192.09±33.92	36.79±11.41	2.18±.96
Control	Post	500.59±61.47	198.18±34.87	34.05±10.10	2.50±1.06
Control	Week 12	506.32±54.34	203.32±29.11	33.50±8.48	2.36±.85
Control	Week 16	514.82±45.68	213.86±29.62	31.99±5.86	2.27±.63
Life Kinetik	Pre	483.86±45.45	187.45±20.79	34.89±9.75	2.41±1.10
Life Kinetik	Post	584.36±38.94	242.14±21.63	17.48±3.64	3.91±1.27
Life Kinetik	Week 12	579.05±39.77	236.05±22.15	18.31±2.97	3.77±1.15
Life Kinetik	Week 16	570.77±38.54	229.23±22.72	19.01±3.15	3.45±.86
Mental Training	Pre	526.68±45.32	212.00±28.31	37.59±7.41	2.09±.81
Mental Training	Post	591.64±40.93	251.73±27.09	14.93±2.45	5.36±1.00
Mental Training	Week 12	588.73±35.58	245.50±20.53	17.78±3.43	4.77±1.02
Mental Training	Week 16	583.68±29.15	241.73±16.84	19.06±4.85	4.32±1.09

Table 2 presents descriptive statistics for all outcome measures across groups and time points (unchanged from the original submission; variables renamed for consistency with the revised Method).

Table 3. Mixed-design ANOVA (3×4), Greenhouse-Geisser corrected

Outcome	Effect	df	F	p	Partial η^2
d2 Attention	Group	2, 63	15.86	<.001	.335
	Time (GG)	1.92, 121.11	122.12	<.001	.660
	Group×Time (GG)	3.85, 121.11	21.40	<.001	.404
d2 Concentration Perf.	Group	2, 63	13.38	<.001	.298
	Time (GG)	2.42, 152.71	84.90	<.001	.574
	Group×Time (GG)	5.216, 164.30	13.37	<.001	.298
NeuroSky Best Time	Group	2, 63	37.35	<.001	.542
	Time (GG)	1.74, 109.63	114.30	<.001	.645
	Group×Time (GG)	3.48, 109.63	17.33	<.001	.355
NeuroSky Barrel Count	Group	2, 63	29.78	<.001	.486
	Time (GG)	2.55, 160.35	71.08	<.001	.530
	Group×Time (GG)	5.491, 172.90	18.61	<.001	.371

Note: GG=Greenhouse-Geisser correction applied (Mauchly's test indicated sphericity was violated for all four outcomes, all $p<.001$).

Table 3 presents the corrected mixed ANOVA results, with full degrees of freedom and Greenhouse-Geisser correction applied throughout (all four outcomes showed a significant sphericity violation, Mauchly's $p<.001$). These results were independently cross-validated

against the original SPSS analysis underlying the doctoral thesis on which this manuscript is based.

Table 4. Within-group pre-post Hedges' g (paired, average-variance standardizer, small-sample corrected)

Outcome	Group	Hedges' g	95% CI
d2 Attention	Control	.135	[.031, .239]
	Life Kinetik	2.289	[1.561, 3.017]
	Mental Training	1.450	[1.002, 1.898]
d2 Concentration Perf.	Control	.171	[-.062, .403]
	Life Kinetik	2.485	[1.687, 3.282]
	Mental Training	1.382	[.932, 1.832]
NeuroSky Best Time	Control	-.245	[-.639, .149]
	Life Kinetik	-2.279	[-3.072, -1.487]
	Mental Training	-3.957	[-5.182, -2.733]
NeuroSky Barrel Count	Control	.304	[-.101, .709]
	Life Kinetik	1.218	[.689, 1.748]
	Mental Training	3.460	[2.324, 4.596]

*Note***:** CI=Confidence interval

Table 4 presents corrected within-group pre-post Hedges' g, calculated with the pre-post correlation incorporated and the small-sample correction applied (see Data Analysis). These values differ from those in the original submission, which could not be reproduced from the reported descriptive statistics under any single standardizer.

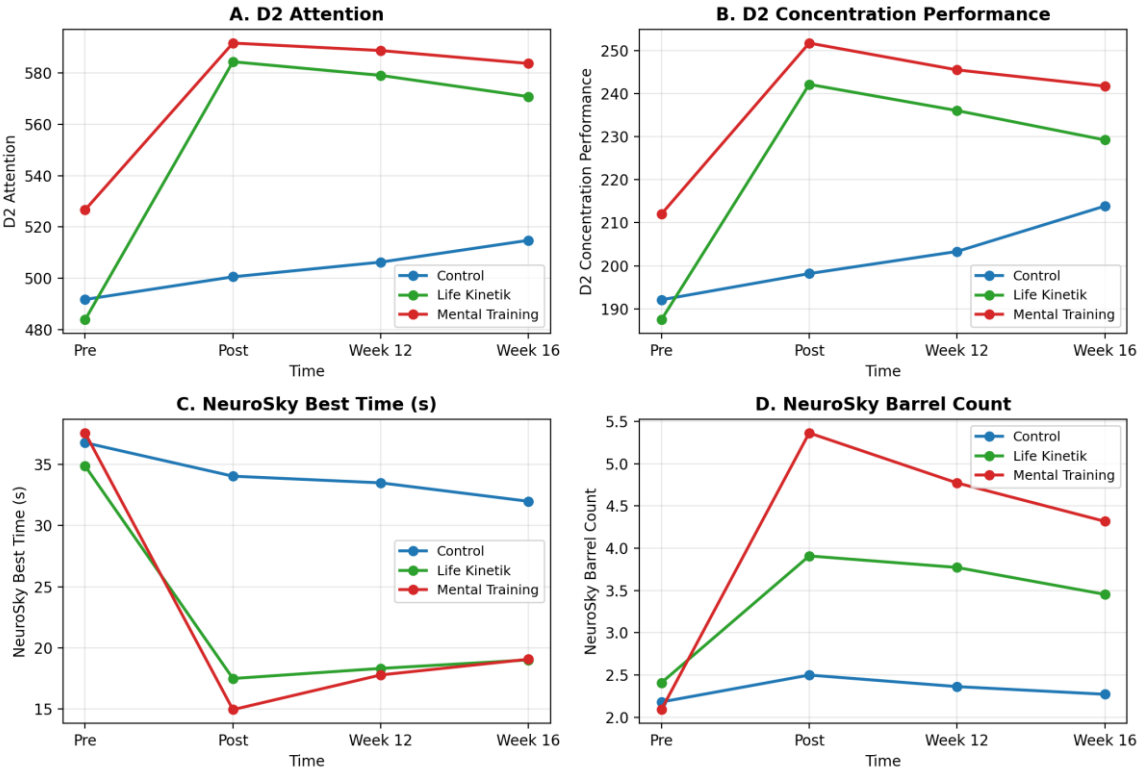
Table 5. Between-group post hoc comparisons

Outcome	Time	MT-LK	MT-Control	LK-Control	Bonferroni p (MT-LK)
d2 Attention	Pre	42.82	34.91	-7.91	.023
	Post	7.27	91.05	83.77	1.000
	Week 12	9.68	82.41	72.73	1.000
	Week 16	12.91	68.86	55.95	.807
d2 Concentration Perf.	Pre	24.55	19.91	-4.64	.014
	Post	9.59	53.55	43.95	.800
	Week 12	9.45	42.18	32.73	.600
	Week 16	12.50	27.86	15.36	.253
NeuroSky Best Time	Pre	2.70	.80	-1.91	
	Post	-2.55	-19.12	-16.57	.565
	Week 12	-.53	-15.73	-15.19	1.000
	Week 16	.05	-12.93	-12.99	1.000
NeuroSky Barrel Count	Pre	-.32	-.09	.23	
	Post	1.45	2.86	1.41	<.001
	Week 12	1.00	2.41	1.41	.005
	Week 16	.86	2.05	1.18	.005

Note: Values are raw mean differences; the Bonferroni-corrected p-value shown is for the mental training (MT) vs. life kinetik (LK) contrast specifically, since this was the previously missing comparison. A dash (-) indicates the omnibus between-group effect at that time point was not significant, so no pairwise contrast was computed. MT-LK, MT-Control, and LK-Control are raw mean differences.

Table 5 presents the complete set of Bonferroni-corrected between-group post hoc comparisons at each time point, including the life kinetik vs. mental training contrasts absent from the original submission. At baseline, Mental Training scored significantly higher than

life kinetik on both d2 outcomes (d2 Attention, p=.023; d2 Concentration Performance, p=.014); no baseline difference was found for the neurofeedback-task variables. From posttest onward, both intervention groups scored significantly better than Control on every outcome (all p<.001). Life kinetik and mental training did not differ significantly from one another on either d2 outcome or on NeuroSky Best Time at any post-intervention time point. The one significant direct contrast between the two interventions was NeuroSky Barrel Count, which favored Mental Training at posttest and Week 12 (p<.001, p=.005) and Week 16 (p=.005).



Note: (A) d2 Attention. (B) d2 Concentration Performance. (C) NeuroSky Best Time (lowerfaster attentional engagement). (D) NeuroSky Barrel Count. Both intervention groups improved markedly relative to Control on all four measures and largely maintained these gains through the Week 16 follow-up, with a partial decline evident between posttest and follow-up on most measures.

Figure 1. Changes in cognitive and neurofeedback-task outcomes over time by group

Because within-group effect sizes conflate treatment effects with practice effects, regression to the mean, and baseline differences, we additionally computed between-group difference-in-change contrasts (independent-samples comparison of Post-Pre change scores). Life kinetik showed a significantly larger raw gain than Mental Training on d2 Attention (Δ=35.55, 95% CI [18.60, 52.50], p<.001) and d2 Concentration Performance (Δ=14.95, 95% CI [4.41, 25.50], p=.020, Bonferroni-corrected). However, this is fully explained by life kinetik's significantly lower baseline (Table 5, Pre row): because both groups converged to statistically indistinguishable posttest and follow-up scores, the larger raw gain reflects regression toward a common ceiling rather than differential efficacy. We interpret efficacy claims in this manuscript accordingly.

Table 6. Confusion matrix, leave-one-out cross-validation

Actual\Predicted	Mental Training	Life Kinetik	Control
Mental Training	17	5	0
Life Kinetik	7	14	1
Control	1	1	20

Note: Overall accuracy=77.3% (95% CI [65.8%, 85.7%]); balanced accuracy=77.3%; chance level=33.3%

A linear discriminant function analysis using post-test scores on all four outcome measures as predictors, evaluated via leave-one-out cross-validation, classified group membership with 77.3% overall accuracy (95% CI [65.8%, 85.7%]) against a chance level of 33.3%. Balanced accuracy was also 77.3%. Per-class sensitivity was 77.3% for mental training, 63.6% for life kinetik, and 90.9% for Control (Table 6). No variable selection was performed prior to cross-validation.

Nearly all misclassification occurred between the two active intervention groups; misclassification involving Control was rare. This pattern is described further, and interpreted with appropriate caution, in the Discussion.

DISCUSSION AND CONCLUSION

This study examined the effects of mental training and life kinetik training on attention and concentration in volleyball players, using the d2 Attention Test as the primary outcome and an attention-contingent neurofeedback task as a supplementary index. Both interventions produced significant, sustained improvements relative to Control. Unlike our original submission, we do not find evidence that either intervention was more effective than the other: the two groups did not differ significantly on either d2 outcome at any post-intervention time point, and the one significant direct contrast between them (NeuroSky Barrel Count) favored Mental Training.

The d2 Attention results indicate that both interventions enhanced attentional performance relative to Control, consistent with prior work on open-skill sport participation and attentional control (Voss et al., 2010; Gu et al., 2019; Koch & Krenn, 2021; Heilmann et al., 2022). The raw pre-post gain on d2 Attention was significantly larger in the life kinetik group than in the mental training group (δ=35.55, 95% CI [18.60, 52.50]); however, this reflects life kinetik's significantly lower baseline score rather than superior efficacy. Because both groups converged to a statistically indistinguishable level of performance by posttest, we interpret the larger raw gain as regression toward a common ceiling. We no longer attribute this pattern to the cognitive-motor integration demands of life kinetik specifically, since the data do not support a between-intervention efficacy difference.

Significant gains were also observed in the Mental Training group on d2 Concentration Performance and on the neurofeedback-task indices, consistent with prior work on the effects of imagery, breathing, and mindfulness-based practice on attentional control (Lotze & Halsband, 2006; Munzert et al., 2009; Vealey, 2024). The neurofeedback-task findings (NeuroSky Best Time and Barrel Count) showed a broadly parallel pattern of change to the d2 results, with significant Group×Time interactions in the intervention groups. We are cautious about the strength of this claim, however. These indices are exploratory, game-derived

outputs of a proprietary, non-validated attention-detection algorithm rather than raw EEG or eSense values (see Method), and we did not conduct a formal test of association between the behavioral and neurofeedback-task change scores. We therefore describe the pattern as broadly parallel rather than as evidence of concordance, and we no longer characterize these findings as evidence about underlying neurophysiological or cortical processes; beta-band EEG activity has been linked to attentional and cognitive processing (Ray & Cole, 1985), and neural-efficiency accounts of expert cognitive-motor performance have been proposed in the sport and psychomotor literature (Li & Smith, 2021; Morrone & Pedlar, 2024); however, these mechanisms were not directly measured in this design.

The discriminant function analysis classified group membership from post-test scores with 77.3% accuracy, well above the 33.3% chance level, but we interpret this cautiously. Because group membership determined the outcomes entered into the model, this analysis mainly demonstrates that intervention status is recoverable from post-test scores rather than providing independent evidence of efficacy. Consistent with this, nearly all misclassification occurred between the two active intervention groups rather than between either intervention and Control, which fits the broader pattern in this dataset: the interventions are readily distinguished from no intervention, but not clearly from each other.

The partial decline in performance observed between posttest and the Week 12/16 follow-up assessments, while scores remained above baseline, suggests that intervention-related gains were largely maintained after the structured programs ended, though regular volleyball training continued throughout for all groups. This is consistent with prior suggestions that continued cognitive stimulation supports the maintenance of cognitive-motor training effects (Herold et al., 2018; Moreira et al., 2021).

The control group showed small, non-significant pre-post changes on most outcomes (Table 4), with the exception of a significant increase in d2 Attention by Week 16 (g=.135, 95% CI [.031, .239]). Given that the d2 was administered on four occasions and Çağlar and Koruç (2006) reported a significant practice effect across repeated d2 administrations in athletes, some portion of this change, and of the intervention groups' improvement, may reflect repeated exposure to the test rather than the interventions alone. We no longer describe the control group's change as negligible. Because the control group received no structured additional contact, nonspecific attention, expectancy, and engagement effects associated with participating in either structured program cannot be separated from the specific content of mental training or life kinetik. This limitation is compounded by the substantial difference in contact time between the two intervention protocols (approximately 56 sessions for mental training versus 16 for life kinetik), which precludes a fair efficacy comparison between them even setting the baseline imbalance aside.

No sport-specific performance outcome (e.g., serve reception, block timing, or match statistics) was assessed in this study; the present findings speak to cognitive outcomes relevant to sport performance rather than to sport performance itself, and we have removed language implying the latter. Overall, the present findings indicate that both mental training and life kinetik training are associated with improved attention and concentration performance in volleyball players relative to standard training alone, with gains largely maintained through

16 weeks. We do not find evidence that one intervention is more effective than the other, and any such claim would require a study with balanced baseline scores, matched intervention dose, and an attention-matched active control to be tested properly.

It should include the explanation and discussion of the findings obtained in the study in the light of the literature. Comparison with the studies in the literature is stated in this section together with the researcher's comments. In this section, the meaning of the findings and the weaknesses or strengths of the study and their limitations should be mentioned. The meaning of the results obtained from the study, unexplained questions, new assumptions when necessary should be stated. The results obtained from the research should be briefly stated.

Recommendations and Limitations

Group allocation was non-random (purposive sampling); life kinetik and mental training differed significantly at baseline on both d2 outcomes, which limits the interpretability of subsequent between-group comparisons as reflecting intervention effects.

The two intervention protocols differed substantially in contact time (approximately 56 sessions for Mental Training versus 16 for life kinetik), and individual-level adherence/attendance data are not available for either group.

The control group received no attention-matched active contact, so nonspecific engagement and expectancy effects cannot be ruled out.

The d2 Attention Test was administered on four occasions; practice effects, documented in the source validation study for this population (Çağlar & Koruç, 2006), likely contributed to some portion of the observed improvement, including in the Control group.

The NeuroSky-derived Best Time and Barrel Count indices are exploratory, game-performance outputs of a proprietary attention-detection algorithm, not raw eSense or spectral EEG measures; the manufacturer's own documentation describes the underlying software's mini-games as illustrative rather than measurement-grade, and we are not aware of a peer-reviewed validation of this specific task in adolescent or athletic samples. Session-level signal-quality data and a formal test-retest reliability estimate are not available.

No direct statistical test of association between the behavioral (d2) and neurofeedback-task change scores was conducted; the parallel pattern of change described in the Discussion should not be read as evidence of concordance.

The discriminant function analysis is best regarded as a descriptive summary of post-test group separability rather than independent confirmatory evidence, since group membership determined the outcomes used to predict it. The complete set of a priori power-analysis parameters could not be verified from the records available to us. No sport-specific performance outcome was measured. The sample consisted exclusively of volleyball players aged 14-16 years in one region, which limits generalizability to other age groups, sports, and settings.

Future studies should use random allocation where feasible, match intervention dose and structure between comparison arms, include an attention-matched active control, and employ validated, research-grade EEG systems (e.g., NeuroSky's NeuroView Research Tools, or

multi-channel systems) if firm neurophysiological conclusions are sought. Coaches and performance specialists may consider incorporating structured cognitive training into regular volleyball training, informed by the present results; combining behavioral and neurofeedback-based assessment may offer a more complete picture of training-related cognitive change, provided the exploratory status of the latter is kept in view.

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Statement of Ethics Committee	
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Generative AI was used only to improve the language and readability of the manuscript. No AI tool was used for data collection, data analysis, interpretation of the results, or generation of the scientific conclusions. All scientific content, analyses, and final decisions remain the responsibility of the authors.	

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