The Cost of Mental Fatigue: A Proposed Model for Integrated Training

Track: Business of Sport

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1. Introduction

Michael Jordan and Tom Brady are widely considered the greatest of all time in their respective sports. Between the two, they share twelve championship victories, ten championship most valuable awards and eight regular season most valuable player distinctions. This data makes a compelling argument. However, as individually talented and accomplished as they are, how successful would they have been if they were standalone entities, without a supporting cast? What would Jordan's legacy look like without Phil Jackson and Scottie Pippen, or Brady's minus Bill Belichick and Rob Gronkowski? The "Jordan effect" theme underscores the Gestaltian notion of the whole being greater than the sum of its parts. The premise is that the value potential of individual components grows exponentially, only when supported by others in complementary harmony. So why is this method not used for the modern-day mental training of the world's best athletes? Across the fields of human performance research, among the most pressing concerns is the role of mental fatigue, which over the course of a practice, game, or season will diminish individual performance while limiting team success. Simply, mental, or cognitive fatigue is defined as a subjective state in which work performance declines after an extended time performing a cognitive task (Macmahon et al, 2014). This affects how the player weeds out distractions, hones in on crucial details, and problem solves the key facets of game time decisions.

The current market status quo of mental skills is meditation; a subliminal-like task of avoidance to distract and then calm the performer. This is an example of escapism; the physical and mental seclusion to create an environmental vacuum, void of stress. This method is the current, normative strategy for such a dilemma. The accommodation of the athlete is also a preferred approach consistent with the herd mentality, designed to make the athlete as comfortable as possible in the face of pressure. While effective in the short-term; much like a tourniquet to stop the bleeding; a more long-term strategy is mandated to assist athletes in the environmental adjustments required for performance demands.

The single model approach that currently saturates the high-performance market of sports presents as a linear model, one where mental skills are presented as a subjective experience based on the athlete's interpretation of their recommended training. This leaves room for ambiguity and promotes a singular, narrow focus of outcome-oriented experience. While this has been the solution for performance, "problems", this experience promotes a one-dimensional, non-fluid, fixed mindset. More significantly, this sends the athlete the subliminal message that stress is a constant problem requiring immediate retreat or a definitive solution. Relevant to mental fatigue, this single model approach promotes that limitations are a constant of performance, thus establishing a ceiling of accomplishment prohibiting the ascension to optimal performance.

The variables that are relevant to stress that coincide with the current status quo of mental skills training stemming from factors interpreted negatively and deemed uncontrollable. This organically creates the presence of discomfort, promoting a natural response that in order for one to deal, one must avoid. Chaos theory states that nothing is random, and everything is deterministic (Matson, 2008). Chaos is defined as the ever-changing variables that place both internal and external demands on your task, disrupting all mental scripts. This promotes stress as a natural phenomenon that cannot be avoided. This realization of acceptance encourages appreciation and increased tolerance of discomfort. Therefore, the paradox that exists is that learning to be comfortable with the uncomfortable promotes a level of flexibility that achieves optimal performance. This can be deemed counter intuitive yet enables us to embrace the very thing we have overlearned to avoid.

A single model approach to mental skills training offers success in its respective applications. Collectively, as an integrated training model approach, the advantages of said success are magnified. Integration Effect is the potentiation of multiple training mechanisms that leverage physiological systems. This interaction enhances the individual model to grow stronger when together, opposed to standing alone.
Integrated training model approach celebrates the process of training via design, that emphasizes an acceptance of failure and a non-judgmental stance. This process over outcome approach encourages a growth mindset, the open stance that promotes flexibility and creativity leading to the greater potential of human development (Chao et al, 2017). This adaptation mechanism reduces fear by embracing chaos as part of experience. Thus, scripts are eliminated, and limits abound.

If the mental fatigue threshold is enhanced, optimal performance is more likely. Accordingly, when collective systems are trained in harmony and integration, the individual performs better. Performance outcomes are less variable, player longevity improves through expansive skill sets, coachability increases and player buy-in creates a more unified culture.

Holistic Performance Theory, (HPT) quantifies the physical and mental skill integration of objective performance. It is the totality of the player's physiological systems that unify mind-body integration. Despite chaos, it is a more determined outcome.

1.1. Performance

Performance is broadly defined by Merriam-Webster as the execution of an action or something that has been accomplished. Performance is not only a crucial aspect of sports and music, but is also relevant in our occupational, academic, and personal lives. What all these domains share is the room for improvement. Currently, the status quo is to improve performance in a linear model, where athletes are trained in a vacuum using a single model approach. While this approach sees success in a traditional sense, there are proposed limitations. To optimally diminish mental fatigue, which is defined as a key correlate in diminishing performance, we must ask what specifically facilitates high-level performance, and how one can train optimally for it? Athletes have innate abilities, while others require rigorous and consistent practice regimens to elevate their performance levels.

We have examined single approaches and the holistic integrated training model approach to determine what is necessary to achieve an optimal level of training. We address this by detailing Holistic Performance Theory and how through integration effect, it influences and ideally improves performance while decreasing mental fatigue. While both models emphasize either a linear or integrated approach, biosensor technology has been successful across domains. Cutting-edge wearable technology based on empirical, scientific data empowers the athlete to leverage their physiology to increase in-game relaxation, focus, and overall performance.

1.2. Holistic Performance Theory

Holistic Performance Theory is a concept encapsulating the most relevant variables of sustained performance. The formulation of these variables creates an opportunity to identify the key areas that, when leveraged, maximize a performer's raw talent for optimal performance.

$$Raw\ Talent\ X\ \frac{Deliberate\ Practice\ X\ Engagement\ (Effort - RPE)}{Mental\ Fatigue}$$

Raw Talent is the first variable in this equation, acting as a multiplier for all others. The most notable model that defines raw talent is Gagne's Differentiated Model of Giftedness and Talent (Fransen, 2018). DMGT holds that some individuals display giftedness, defined as "the possession and use of outstanding (i.e. top 10%) natural abilities that can best be identified in childhood and that manifest in the facility and pace with which individuals acquire new knowledge and skills (Fransen, 2018)." Gagne's model also identifies the role of personal factors in order to better understand the degree of these abilities (i.e. intrapersonal, physical, psychological [e.g. temperament and volition] and environmental [e.g. opportunities and social support]). These factors play a role in higher displayed abilities, accelerated development, and an ability to reach a peak more quickly with training (Fransen, 2018). Raw talent are the elements of a performer that are not obtained through outside training. Instead, the elements that comprise raw talent are relatively set like height, hand size, and muscle fibers from birth. This predetermined skill set creates a range of ability for the performer. Everyone has a set range that can either be fostered to reach their peak or hindered to be just potential. As raw talent is unchanging and unique to the individual, the most important aspect is the degree in which it can be developed. Holistic Performance Theory postulates that the interaction of deliberate practice, engagement, and mental fatigue are all variables requiring a closer look when maximizing raw talent.

Currently, performers practice in a variety of ways. These various methods can present as simple performance-simulation (i.e. scrimmaging), repetition, or skill development. HPT proposes that the ideal practice method is deliberate practice. To practice activities deliberately refers to activities performed in a purposeful and systematic (i.e. daily), work-like manner. These activities do not lead to immediate rewards, and they require optimal effort and attention (Ericsson et al., 1993). Research shows that this specialized form of practice is better than regular practice alone, specifically indicating a positive relationship between hours of deliberate practice and increased sport performance. Intermediate and expert level Gaelic football players' practice habits were studied by Coughlin et al. (2014). Research examined that when each level of player was asked to practice strengths or weaknesses, the experts choose to work on their weaknesses more often. The results showed less overall enjoyment, but higher levels of effort as compared to the intermediate level players who choose to work more on strengths. Thus, an elite level player is more likely to practice deliberately with the intention of improving a specific skill.

Ray Allen is the consummate example. Him making, not taking, three-hundred shots from each spot around the 3-point perimeter leads to favorable outcomes. Therefore, that deliberate practice on a specific skill; compounded over-time; creates a more detail-oriented, versatile player.

Engagement is constructed by two components, one positive and one negative; effort and rate of perceived exertion (RPE); with RPE detracting from effort. Effort is defined as how hard a performer will try in the given situation, while RPE is how difficult that person believes the task to be and the relationship of effort and outcome. The perception in RPE affects the degree to which the performer believes they can succeed and how hard they will then continue to work. Thus, if a performer perceives a given result should be achieved based on their level of effort; and when not the case; the performer's effort on successive tries diminishes. This is associated with performance when an individual feels their RPE is high. As a result, they will have difficulty sustaining the mental and physical energy needed for training, impacting their level of performance. This has been exemplified in the powerlifting world and is currently measurable by the Borg Scale for RPE and various effort indices (Haddad et al, 2013). Holistic Performance Theory highlights these factors as highly relevant, as they directly contribute to the denominator of human performance: mental fatigue.

In this formula, mental fatigue consists of motivation and energy. Engagement and motivation show a negative relationship. As RPE increases it subsequently diminishes effort and as a result, decreases motivation. This is problematical, as motivation in sport is identified as the key determinant behind every action taken and every effort exerted (Ryan & Deci, 2000). Mental fatigue; a state of cognitive decline; serves as a significant limitation in achieving peak performance. In a 2014 study conducted by MacMahon et al., researchers examined runners' ability to sustain a run, following either a cognitive demanding task or not (control group). At relatively the same level of motivation, when cognitive fatigue was a factor, performance suffered (MacMahon, et, al., 2014). Moreover, when the runners were mentally fatigued, they were less likely to accurately identify their limits.

1.3. HRV, EEG, & NMT

Biosensor technology, the technique of using equipment to reveal human beings some of their internal, physiological events, normal and abnormal, in the form of visual and auditory signals in order to teach them to manipulate these otherwise involuntary or unfelt events by manipulating the displayed signals, (Basmajian, 1989). Thus, biosensor technology, despite their seemingly esoteric and even science fiction flavor, should act to standardize relaxation training and make it more reliable.

Heart rate variance, or HRV, is a metric commonly used in biomedical, psychological, and biological research. HRV is defined as the heart's beat to beat variation, measured in time. Respiratory Sinus Arrhythmia is a key element of HRV examining the relationship between synchronicity and respiration (Yasuma, 2004). HRV is an indicator of physical health and varying degrees of stress; low HRV has been associated with overall mortality and markers of disease (Thayer, Ahs, Fredrickson, Sollers, & Wager, 2012). The connection between optimal performance and ideal heart rate and heart rate variance have long been established. Single model approach HRV training is currently being performed in Major League Baseball and Olympic Training.

The ability to shift focus from internal and external stimulus empower an athlete to manage stress and concentrate at high levels. Most commonly in traditional sport psychology, a single approach model of focus and relaxation techniques are taught to refocus an athlete's attention. Electroencephalogram (EEG) has been a growing tool in attentional training, whereby an athlete utilizes neurofeedback synchronization methods, to decrease levels of anxiety, while concentration and performance improve (Basmajian, 1989). Research supports that the amplitude of resting state cortical EEG rhythms have been shown to be higher in elite athletes compared to amateur athletes and non-athletes (Babiloni et al., 2009). Also, the stronger the background neural synchronization at resting state, the better the cognitive performance when the subject is engaged in cognitive-motor tasks (Babiloni et al., 2009). This type of neurofeedback training encourages a more holistic synchronization of the mind and body. These techniques have been implemented successfully in the world of professional sports, most notably with beach volleyball gold medalist Kerri Walsh Jennings (Sneed, 2017).

Engagement is crucial for optimal performance and can be trained by enhancing neuroplasticity. Neuromuscular timing, (NMT), is an approach that fosters and strengthens neural pathways; stretching the brain's capacity to acquire and crystallize new information. Utilized in cognitive training and rehabilitation programs, this platform leverages timing and rhythm to promote neural plastic enhancement. NMT helps train the body to be more holistically in-tune with its physiology to strengthen a performer's decision-making, timing, and self-awareness while reducing impulsivity. NMT targets executive functioning; specifically, the prefrontal cortex; building a better relationship between motor regulation and attentional direction, improving the capacity to attend and learn, (Shaffer et al.) In addition, NMT has been implicated in helping those to attend to information better, which can impact a host of clinical domains, including processing speed, working memory and self-monitoring.

1.4. Research Hypotheses

The purpose of this study was to identify the degree by which organizations invest in single approach training methodology in comparison to an integrated training model approach, evoking more neurological development. In addition, the degree to which each training approach has on influencing, enhancing, or decreasing performance as defined by the elements of HPT. Therefore, we hypothesize that:

1) An integrated training model approach will have a more *positive* effect on performance, as defined by Holistic Performance Theory, than a single model approach.
2) An integrated training model approach will have a *negative* effect on mental fatigue more than a single model approach; cognitive endurance will increase.
3) An integrated training model approach will have a more *positive* effect on deliberate practice than a single model approach; more engagement in deliberate practice with greater impact on performance.
4) An integrated training model approach will have a more *positive* effect on effort than a single model approach; more effort with greater impact on performance.
5) An integrated training model approach will have a more *positive* effect on raw talent than a single model approach; positive impact on raw talent with greater impact on performance.
6) An integrated training model approach will have a more *negative* effect on rate of perceived exertion (RPE) than a single model approach; RPE will decrease with greater impact on performance.

2. Method

2.1. Procedure

2.1.1. Search Strategy

The PsycINFO, PubMed, and Google Scholar databases were searched to find peer reviewed journal articles. The search strategy used included key terms related to the different aspects of HPT, along with HRV, EEG and NMT. Keywords included “raw talent”, “quality practice time”, (“effort and performance”) and (“rate of perceived exertion and performance”), “rate of perceived exertion”, (“RPE and performance”), “motivation” (“motivation and performance”), “energy”, (“energy” and “performance”), “athlete”, “EEG”, “mental fatigue”, “heart-rate variability”, “HRV”, (“HRV and performance”), “cognition”, “biofeedback”, “respiratory sinus arrhythmia”, and “baroreflex”. Additional keywords consisted of “NMT”, “interaction effect”, “cognitive endurance”, “integration of biofeedback” and “mental fatigue”. The search strategy was created by the authors and given the broad range of eligible studies; we did not use any additional search filters. Additional data sources for analysis were collected through Cochrane Reviews. The final database search was conducted in September 2020.

2.1.2. Screening and Selection

The titles and abstracts retrieved from the search were independently screened by five reviewers to identify empirical studies that included: 1) a human sample, 2) research in which the authors collected their own data, 3) research completed within the past 20 years. Inclusion criteria consisted of articles based on performance, randomized control trials (RCTs), studies that had a cross comparison between an experimental and control group, and studies that had similar effect sizes. External validity was considered in selection of research articles in addition to studies with similar sample sizes. Exclusion criteria consisted of articles older than 10 years, non-peer-reviewed articles, articles with a small sample size ($n<10$), research that did not have a comparison group, and studies that had contrasting effect sizes were also excluded.
Potentially eligible studies were retrieved for full-text review and independently assessed for eligibility for inclusion independently by five reviewers. Any disagreement on eligible articles was discussed with a sixth reviewer. All publications received throughout the review process were stored in an electronic database on Google Drive and the reasons for exclusion were recorded by each reviewer. Ultimately, seven research articles were selected for inclusion in which the sample sizes ranged from 14 to 74 participants in each study; the total n for the meta-analysis and regression was $n=177$.

The data from each of the studies was taken to further study the quality of the research and so that the data could be synthesized. Information that was taken from each of the research studies included the methodology and results. When the data was unclear to the authors they would respond by consulting with one another for agreed upon clarification on interpretation of the data.

2.2. Data Extraction, Initial Appraisal and Preparation

2.2.1. Data Coding

Data was coded by quantifying data from the selected research studies based on whether or not the training method had an effect on a part of HPT. If there was an effect on HPT, the grouping variable would be "1" and if there were no grouping variables, it was coded as "0". If there was improvement in the HPT skill, it was coded as a "+1", supporting the null was coded as "0" and a decrease in the skill was coded as "-1". Specifically, reviewers would code data based on if EEG, HRV, NMT or the integration of the three components was present in the study and if it impacted a part of HPT. If the integration of EEG, HRV, or NMT was present in the study in relation to an aspect of HPT, the authors further studied if the integration of such components was more impactful for an element of HPT. This data was then transferred into a spreadsheet for extraction and analysis.

Study_ID	Year	N	MF	RPE	QP	EFFORT	RT	ES	HRV	EEG	NMT
Babiloni et al.	2009	74	0	0	0	0	1	0.313	0	1	0
Baden et al.	2004	40	-1	1	0	1	0	3.547	0	0	1
Diekfuss et al.	2019	17	0	0	1	1	0	0.74	0	0	1
Dziembowska et al.	2016	48	0	0	1	1	0	0.473	1	1	0
Gergelyfi et al.	2015	18	-1	0	0	1	1	1.008	1	1	0
Nakamura et al.	2010	15	-1	1	0	1	1	1.806	0	0	1

Biosensor tools (HRV, EEG, NMT); 1 = YES, 0=NO. HPT Skills(MF,RPE,QP,EFF,RT); 1 = improvement, 0 = Null, -1 = decreased

2.2.2. Data Extraction

The effect size was extracted from each of the seven research articles that were chosen for the meta-analysis. To convert each effect size into Cohen's d a conversion table by Jared DeFife, Ph.D. from Emory University was used. In addition to this, the standard deviation and standard error were calculated for each of the research studies. The weight of each effect size was produced by RevMan which was also used to run the meta-analysis.

2.2.3. Data Analysis

Data was analyzed using a predictive regression model investigating the relationship between the independent variables (Biosensor tools; HRV, EEG, NMT) and the dependent variables (HPT skills; QP, RT, MF, RPE, EFF) through Stata's statistical software. Conducting a multiple linear regression analysis of the seven studies, revealed the relationship between training approaches (HRV, EEG, and NMT) and performance markers (raw talent, quality practice time, effort, RPE, and mental fatigue).

A meta-analysis was run through the Cochrane review software, RevMan 5. The strength of the Integration Effect of the Biosensor tools (HRV, EEG, NMT) was analyzed to determine if an effect exists and if the effect is positive or negative. The meta-analysis was conducted using the random-effects model, and a Z-test was run to assess the overall effect size. In addition to this, the meta-analysis was used to identify any threats to external validity.

3. Results

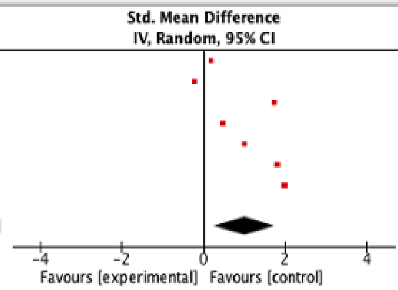
3.1. Meta-analysis Summary

A meta-analysis was conducted on seven studies (N = 177) using the random-effects model displayed in the Forest Plot in Figure 1. All effect sizes were converted to Cohen's d, utilizing Dr. Jared DeFife's conversion spreadsheet for ease of analysis. The overall effect estimate was 1.00, with the confidence intervals ranging from [0.25 – 1.74]. A significant Z test was run, Z = 2.63 (P=0.008), displaying the significance of the weighted average effect size. High levels of Heterogeneity were predicted ($Tau^2 = 1.00$, $I^2 = 100\%$), reporting that the meta-analysis was unreliable.

Figure 1. *Forest Plot*

Study or Subgroup	Std. Mean Difference	SE	Experimental Total	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
Babiloni et al. 2009	0.185	0.0009	44	30	14.3%	0.18 [0.18, 0.19]
Baden et al. 2004	-0.221	0.0201	22	22	14.3%	-0.22 [-0.26, -0.18]
Diekfuss et al. 2019	1.74	0.0007	16	13	14.3%	1.74 [1.74, 1.74]
Dziembowska et al. 2016	0.473	0.0087	24	24	14.3%	0.47 [0.46, 0.49]
Gergelyfi et al. 2015	1.008	0.0122	18	18	14.3%	1.01 [0.98, 1.03]
Nakamura et al. 2010	1.806	0.021	15	15	14.3%	1.81 [1.76, 1.85]
Shaffer et al. 2000	1.98	0.0016	38	18	14.3%	1.98 [1.98, 1.98]
Total (95% CI)			**177**	**140**	**100.0%**	**1.00 [0.25, 1.74]**

Heterogeneity: $Tau^2 = 1.00$; $Chi^2 = 2112345.64$, df = 6 ($P < 0.00001$); $I^2 = 100\%$
Test for overall effect: Z = 2.63 (P = 0.008)



Meta-analysis of association between biosensor tools (HRV, EEG, NMT) on HPT skills (RPE, QP, MF, EFF, RT) overall effect size.

3.2. Regression Summary

A multiple linear regression analysis of the seven studies (N=177) identified the relationship between the training approaches (HRV, EEG, NMT) and the performance markers (Raw Talent, Quality Practice, Effort, RPE, Mental Fatigue) as displayed in Table 1. The effect size mean was used as weight (wRT, wQP, wEFF, wRPE, wMF) of each variable for accuracy by multiplying each performance marker by the aggregate number of participants. Each training approach was multiplied by the corresponding Effect Size to attribute the study's weight of importance. The results found that Raw Talent (wRT, M= 26.285) and Effort (wEFF, M = 25) displayed the most substantial positive relationship indicating that the integrated training model approach increases these specific performance variables. Mental Fatigue (wMF, M= -7.71) displayed a strong negative relationship, indicating that the integrated training model approach decreases Mental Fatigue over time. RPE (wRPE, M= 0.857) and Quality Practice (wQP, M=17.285) also had positive relationships, supporting an integrated training model approach to have a more positive relationship with improved cognitive endurance than single approach training.

Table 1. *Regression Summary*

Variable	N	Mean	SD	Min	Max
Article	7	1	0	1	1
year	7	2010.429	6.803361	2000	2019
n	7	35.57143	23.58571	15	74
ES	7	0.996	0.8744467	0	1.98
MF	7	0.4285714	0.5345225	-1	0
RPE	7	0.4285714	0.5345225	0	1
QP	7	0.4285714	0.5345225	0	1
EFF	7	0.8571429	0.3779645	0	1
RT	7	0.7142857	0.48795	-0.22	1
HRV	7	0.2857143	0.48795	0	1
weight	7	14.31429	21.82746	0.1	55.3
wRT	**7**	**26.28571**	**28.18223**	**0**	**74**
wMF	**7**	**-7.714286**	**9.776064**	**-21**	**0**
wQP	**7**	**17.28551**	**24.6219**	**0**	**56**
wEFF	**7**	**25**	**24.6219**	**0**	**56**
wRPE	**7**	**12**	**18.08314**	**0**	**48**
wHRV	7	0.0857143	0.1573592	0	0.4
wEEG	7	4.871429	12.62494	0	33.5
wNMT	7	9.442857	20.60055	0	55.3

Significant results were found for all integrated weighted skills: Raw Talent (wRT, M=26.285); Mental Fatigue (wMF, M= -7.714286); Quality Practice (wQP, M = 17.28551); Effort (M = 25); Rate of Perceived Exertion (wRPE, M = 12).

3.3. Regression x Heart Rate Variability

The relationship between Heart Rate Variability (HRV) and the performance markers displayed nonsignificant effects; wRT M= -.0010 p= 0.769, wQP M = .0021 p = 0.825, wEF M = -.0012 p = 0.925, wRPE M = .0048 p = 0.450 , wMF (omitted due to collinearity) as displayed in Table 2. These results indicate that although HRV has significant effects (as reported in the literature reviews), when run against the performance markers being analyzed, no effect was detected on the single approach analysis.

Table 2. *HRV Regression Analysis; Single Approach*

Variable	SS	df	MS		
				N =	7
Model	0.081214874	4	0.0203	F(4, 2) =	0.6
Residual	0.67356559	2	0.03368	Prob > P =	0.7012
Total	0.148571433	6	0.02476	R = squared =	0.5466
				Adj R - Squared =	-0.3601
				Root MSE =	0.18352

wHRV	Coef.	SE	t	P > | t |	[95% Conf.	Interval]
wRT	-0.010789	0.003219	-0.34	0.769	-0.0149279	0.01277
wMF	0	(omitted)				
wQP	0.0021391	0.008519	0.25	0.825	-0.0345133	0.0387916
wEFF	-0.0011597	0.010851	-0.11	0.925	-0.0478495	0.0455301
wRPE	0.0048535	0.005213	0.45	-0.0175752	0.0272823	0.0272823
_cons	0.0478475	0.201949	0.024	0.821067	0.9167621	0.9167621

No significant effects were found: wRT M = -.0010 p= 0.769, wQP M = .0021 p = 0.825, wEF M = -.0012 p = 0.925, wRPE M = .0048 p = 0.450, wMF (omitted due to collinearity).

3.4. Regression x Electroencephalogram

Raw Talent and Effort both displayed over 95% confidence intervals. Raw Talent (wRT M= .328 p = 0.03) was found to have a significant positive p-value and Effort (wEF M= -.973 p = 0.039) was found to have a significant negative p-value, as displayed in Table 3. These results show that although EEG has significant effects on other skills (as reported in the literature review), EEG alone is insufficient to assess the analyzed performance markers.

Table 3. *EEG Regression Analysis; Single Approach*

Variable	SS	df	MS		
				N =	7
Model	933.587105	4	233.397	F(4, 2) =	20.52
Residual	22.7471804	2	11.3736	Prob > P =	0.047
Total	956.334286	6	159.389	R = squared =	0.9762
				Adj R - Squared =	0.9286
				Root MSE =	3.3725

wEGG	Coef.	SE	t	P > | t |	[95% Conf.	Interval]
wRT	0.3283165	0.05915	5.55	0.031	0.0738156	0.5828174
wMF	0	(omitted)				
wQP	0.5076108	0.156546	3.24	0.083	-0.1659505	1.181172
wEFF	-0.9735562	0.199416	-4.88	0.039	-1.831573	- 0.1155394
wRPE	0.2705268	0.095795	2.82	0.106	-0.1416454	0.682699
_cons	8.559565	3.711202	2.31	0.147	-7.408449	24.52758

Raw Talent and Effort both displayed over 95% confidence intervals with Raw Talent (wRT, M = .328 p = 0.03) having a significant positive p value and Effort (wEFF, M = -.973 p = 0.039) having a significant negative p-value. Mental Fatigue, Quality Practice and Rate of Perceived Exertion showed no significant effects.

3.5. Regression x Neuro-Muscular Timing

Neuro-Muscular Timing (NMT) was found to have negative trends (wRT M = -.6537 p = 0.119, wEF M = 1.461, wRPE M = -.8719 p = 0.162), most significantly with effort as displayed in Table 4. Quality Practice (wQP (M = 1.389, p = 0.169) displayed a strong significance. Neuro-Muscular Timing has significant effects (as displayed in the literature review); however, small effects for the performance markers being analyzed were found. NMT can be estimated to be an effective training tool for Quality Practice and Mental Fatigue, with future research necessary to determine the clinical significance.

Table 4. *NMT Regression Analysis; Single Approach*

Variable	SS	df	MS		
				N =	7
Model	2145.84296	4	536.461	F(4, 2) =	2.68
Residual	400.454113	2	200.227	Prob > P =	0.2898
Total	2546.29707	6	424.383	R = squared =	0.8427
				Adj R - Squared =	0.5282
				Root MSE =	14.15

wNMT	Coef.	SE	t	P > | t |	[95% Conf.	Interval]
wRT	-0.6537485	0.248179	-0.263	0.119	-1.721578	0.4140811
wMF	0	(omitted)				
wQP	1.389853	0.656831	2.12	0.169	-1.436261	4.215968
wEFF	-1.46103	0.836705	-1.75	0.223	-5.06108	2.139019
wRPE	-0.8719361	0.401934	-2.17	0.162	-2.60132	0.8574474
_cons	49.59149	15.57138	3.18	0.086	-17.40676	116.5898

Quality Practice (wQP, M = 1.389, p = 0.169) is the only variable that displayed a significant effect.

4. Discussion

Throughout the course of performance analysis, the one constant that impacts the athlete is the presence of unknown variables. These variables, to date have been referred to as the intangible markers that can be seen but not measured. The "eye test" or subjectivity have encapsulated the IT factor for athletes since the beginning of gameplay.

This concept is best exemplified by the Society for American Baseball Research, (SABR) and the sport analytic world they have created. This is affectionately known as the "Moneyball" movement, where the organization attempts to predict the chaotic nature of the baseball environment with metrics that operationally define physical aspects of the game.

In the ever-changing business world of sport performance, mental skills remain a subjective experience, both for the trainer and trainee. Current research indicates the advantages of single model approaches on performance. Yet, despite these advantages, a limitation exists where mental skills remain unpredictable with a wide variance of optimal return. This is so because the training process is vacuumous; without the undeniable chaos of unpredictable gameplay; where performers are limited to a one-dimensional, problem-solving approach.

Three regression analyses were used to examine the impact the independent variables had on the dependent variables associated with HPT. HPT research indicates that performance is optimized by enhancing skills and making the performer more aware of their psychophysiological experiences. It also acknowledges how each aspect of HPT is important to identify how performers can create confidence, a sense of pride and a feeling of accomplishment. Aligned with the Gestaltian notion of the whole being greater than the sum of its parts, the primary focus of this study was to measure how the dependent variables would be impacted comprehensively by the integration of HRV, EEG and NMT.

Research on performance has indicated that when cognitive endurance is high, performance increases. Our research found that an integrated training model approach is more effective than a single model approach for combating mental fatigue. By implementing an integrated training model approach, a General Manager, Director of Player Development, and a coach can all provide a wider array of tools for players to improve their cognitive endurance, thus decreasing mental fatigue. Subsequently, the players have greater ability to manage stress, improve decision-making, decrease impulsivity, and emotionally regulate in real time. All these factors lend aid to the player and bolster performance. Based on the results of this study, Integration Effect data supports that performance can be heightened with greater cognitive endurance; thus, decreasing mental fatigue, when compared to traditional single model training mechanisms.

Overall, the results of the study support the hypothesis that an integrated training model approach has a more positive effect on performance than a single model approach. Mental strength; the by-product of an integrated training model approach; is most salient when utilizing biosensor technology combined in sequence, to train the fundamental challenges of maximizing raw talent. Our results found that the benefit of an integrated training model approach maximized the gains of HRV, EEG, and NMT; demonstrating an additive gain as a greater whole; than each by themselves (e.g. Singularly 5,5,5 and Integrated 10,10,10). This proposed training model has the potential to demonstrate a mechanism for athletes to expedite their learning curve from pre-draft selection to professional readiness.

The results of a single model approach were found to have a significant positive effect on performance. However, as compared to an integrated training model approach, a single model approach was less effective in achieving higher levels of performance. Organizations committed to improving their players return on investment (ROI) would benefit from implementing an integrated training model approach for mental strength development. This is either in lieu of current systems or as an additive to current mental skills programs.

Additionally, results supported the hypothesis that an integrated training model approach would have a more positive effect on Effort and Raw Talent than a single model approach. These findings were found to be the most substantial effect size. The results again indicate that although a single model approach is effective, an integrated training model approach allows for optimization of key domains. In addition, a positive relationship was found between an integrated training model approach and RPE, and Deliberate Practice. These findings indicate that the raw skills of players can be more optimally developed, maximizing the potential of every player. In essence, the limits of a player's full potential; once thought to be their ceiling; is inaccurate, revealing their true maximal ability.

The mind is an integral part of managing the physiological systems necessary for performance. Mental skills training, an element that has been taught by sitting/lying down, retreating to a quiet room, and closing one's eyes neglects the organic, chaotic nature of performance. Much like a muscle needing to be torn while working out and then rebuilt through recovery, so must the brain. Advanced neuroscience identified neuroplasticity as the brain's developmental tool (Voss, et al., 2017). Integrated training approaches incorporate more chaotic features to challenge the brain, forcing a neurocognitive synchronization of the mind and body. Thus, developing mental strength; which maximizes the systems necessary to fill the gap in performance; unlocks the athlete's true abilities.

5. Future Directions

As a result of the study, future research is necessary to continue the predictive effects of an integrated training model approach. Based on our results, there is a multifaceted effect on performance as it relates to Holistic Performance Theory. Research must go beyond the current scope of the meta-analysis and begin focusing on a scaled data collection of performers. A more comprehensive data set comprising a multitude of sports would yield more sport-specific training data and outcomes. Through these methods the synchronization of data would enable a more accurate predictive model for training mental strength. The research goals are aspirational as well, to expand on the current theory, where data is required to support or modify our findings. We believe that with these findings, we can begin to utilize this intervention with professional athletes for an additive effect on prior athletic performance training, as well as enhancing or refining the implementation of current mental skills to improve performance.

6. Limitations

The Random Effects meta-analysis reported the overall effect estimate as significant; however, the external validity threats established this analysis as unreliable. The high level of heterogeneity was due to potential publication bias as the selected peer-reviewed articles reported only significant effects lacking variance.

The Regression analysis supported the hypothesis that an integrated training model approach had a more positive relationship with improved cognitive performance than single approach training. More specifically, using HRV, EEG, NMT on their own showed to have improvement (as reported in the literature review). Due to minimal data, the relationship comparison between integrated and single approach was not fully applicable. This was due to collinearity, resulting in the system omitting data from the single approach analysis (See tables 2,3,4). The limited data was the most problematical, diminishing generalizability.

7. Implications

Impacting the bottom line of sport performance is paramount to the business of sports. Athletes who engage with integration training can improve their athletic performance, and although a singular part of a team, can influence the final outcomes of the team goals. The road to team goals always leads to championships. This impacts the overall value of the organization via a winning status and the notoriety that follows. The impact on the business of sport allows franchises to continue their market expansion, recruit higher quality athletes, gain public appeal, and increase revenue. Seeing as integration training is evidently capable of increasing performance (Lehrer et al., 2020), as well as have positive effects on sports performance (Morgan & Mora, 2017), it is a worthy addition to the typical training regimen of elite performance athletes in any sport.

An integration training model approach may be especially beneficial to individual sport athletes, for the purpose of mental wellness (Ströhle, 2019). The cost of mental health is high (Hu, 2006) and taking an approach that attends to both sports performance enhancement and buffering against the effects of mental health is an ethically sound, and financially responsible decision. The cost of mental health on economics is large; a systematic review with cost of illness methodology showed that national economic cost of mental health conditions was 1-2% of total health care costs (Hu, 2006). Based on 2017 data from the CDC (2020), this would amount to $34 billion per year in expenses on mental health alone. Configure those estimates into a sports organization, and the losses are profound.

The implication of the result of this study indicates that an integrated training model approach diminishes the effects of mental fatigue. As a result, synchronicity of the whole performer is achieved, maximizing the opportunities for optimal performance. Based on these findings organizations, front-offices, coaches, trainers, agents, and players alike would all benefit from the adoption of an integrated training model. Founded on the mathematical notion of Chaos Theory, nothing is random, and everything is deterministic. Massachusetts Institute of Technology researchers, physicist Tristan Gilet and mathematician John Bush identify that performance is “affected by the lack of precision on the initial conditions of a system. So, unless you know the exact initial conditions of a system, any uncertainty will be amplified and you will lose predictive power” (Matson, 2008). Thus, a performer who becomes less rigid and impulsive, more regulated and accepting; stemming from the by-products of an integration training model approach; will be more likely to embrace chaotic uncertainties, enabling the replication of a once-in-a generation athlete for all.

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