ORIGINAL ARTICLE

Effect of three months high-intensity anaerobic treadmill-based exercise on intuitive decision-making capability: A prospective cohort study

ASBAH FAISAL[1], MABEL WAQAR[2], TATHEER FATIMA[1], MEHA FATIMA AFTAB[1] ✉, MUHAMMAD ATHAR KHAN[3]

[1]*Dow Institute of Medical Technology. Dow University of Health Sciences. Karachi, Pakistan.*

[2]*Dow Medical College. Dow University of Health Sciences. Karachi, Pakistan.*

[3]*Department of Community Medicine and Dentistry. Liaquat College of Medicine and Dentistry. Karachi, Pakistan.*

ABSTRACT

Background. Quick decision making capability is critical for handling critical situation. Intuitive decision making is most desirable for situations requiring quick and heedful decisions. Decision making, just like other cognitive skills can be modified through several factors like physical activity. In this study we aim to decipher the effects of high-intensity treadmill-based exercise on intuitive ability. Methods. A prospective cohort design with convenience sampling with a sample of 80 participants from various gym centres. Following ethical approval and informed consent, participants were divided in to either no exercise (NE) (n = 38) condition or treadmill-based exercise (TBE) group (n = 42). Data on socio-demographic characters, self-reported mental health history and IDM scores were obtained. Data were obtained at baseline and after 34 sessions of treadmill-based exercise for TBE and 12 weeks of normal physical activity for NE group. Mixed-factor ANOVA, paired t-test and regression analysis was used utilizing SPSS version 21. Results. A significant improvement in IDM scores was observed in TBE group after 34 exercise sessions as compared to NE group ($p < .01$). A significant interaction of time points and group was also revealed through mixed-factor ANOVA ($p < .01$). Socio-demographic characters and mental health history had no significant impact on IDM scores. Chi-square analysis of the IDM sub-categories showed a significant increase in intuitive decision making individuals in the TBE group post intervention ($p < .01$). Conclusion. Exercise training can be used as a potential training tool for improving decision making outcomes in critical settings.

Keywords: Exercise, Decision making, Intuition, Cognition, Mental health.

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✉ **Corresponding author.** *Dow Institute of Medical Technology, Dow University of Health Sciences, 111 Suparco Rd, Gulzar-e-Hijri Gulzar E Hijri Scheme 33, Karachi, 75270, Sindh, Pakistan.*
E-mail: meha.fatima@duhs.edu.pk
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INTRODUCTION

Decision making is a crucial trait in a wide variety of domains including social (Bruch & Feinberg, 2017), medical (Veldwijk et al., 2016), military (Thunholm, 2009) etc. While decision making can be spontaneous, rational, intuitive, dependent or avoidant, intuitive decision making is considered as irrational (Hassani et al., 2016), whereas, importance of intuitive decision making in evident in multiple disciplines and education and training has shown to play an important role in refurbishing intuitive decision making (Ruzsa et al., 2020). Intuitive decision making differs from rational decision making in a way that it doesn't involve logical reasoning but is rather based on past experiences and learning (Calabretta et al., 2016). Intuition is the apprehension of things in absence of logic and follows concepts or facts stored in the brain (Matzler et al., 2007). Rationality and intuition are fundamentally essential for judicious and tactical decision making however both greatly contrast with each other. Intuitive decision making provides quick processing of a large amount of information and is most likely to provide accurate judgments when based on relevant experiential learning (Patterson et al., 2013). Unlike reasoning, intuition is low effort and does not compete for central working memory resources, thereby holding importance in emergency situations. So far, researchers have also elevated the idea that making everyday life decisions intuitively facilitates a positive mental state. It also influences a patient's life and clinician decision-making and behaviour (Buetow & Mintoft, 2011). Since Intuitive Decision Making involves less time and quick coordination among experiences it can serve as a great tool in the contemporary culture for successful decision making.

Much evidence shows that physical exercise (PE) is a strong gene modulator that induces structural and functional changes in the brain, determining enormous benefits on both cognitive functioning and well-being (Mandolesi et al., 2018). Scientific evidence based on neuroimaging approaches over the last decade has demonstrated the efficacy of physical activity in improving cognitive health across the human lifespan. New evidence indicates that exercise exerts its effects on cognition by affecting molecular events related to the management of energy metabolism and synaptic plasticity. Recent studies show that exercise collaborates with other aspects of lifestyle to influence the molecular substrates of cognition (Gomez-Pinilla & Hillman, 2013).

Memory has been found to be related to intuition and intuitive processes both neuroanatomically and experimentally (Frank et al., 2006). Since memory and attention span are related to intuition and intuitive decision-making and physical exercise has profound positive effects on memory and attention (Micklewright et al., 2017), we hypothesize that physical exercise can also directly positively affect intuitive decision making. The aim of this study is to assess the impact of regular exercise on intuitive decision making in a sample of healthy population as compared to controls with active lifestyle in absence of regular exercise.

METHODOLOGY

Participant recruitment and sample selection

Eighty participants (sociodemographic characteristics of the participants are presented in Table 1), were recruited from fitness centres and clubs, after obtaining informed consent after 15 minutes of explanation of the study design and measuring variables (Figure 1). Individuals aged between 18 to 45 years (both males and females) were included while those with any known lower limb deformity, and current diagnosis of psychological disorder were excluded. Ethical approval was obtained from Institutional Review Board, DUHS (Approval No. IRB/1118/DUHS/Approval/2018/198) in accordance with the guidelines of National Bioethics Committee (NBC), consistent with the guidelines set forth in the Helsinki Declaration of 1975. Written and informed consent was obtained from participants prior to the study.

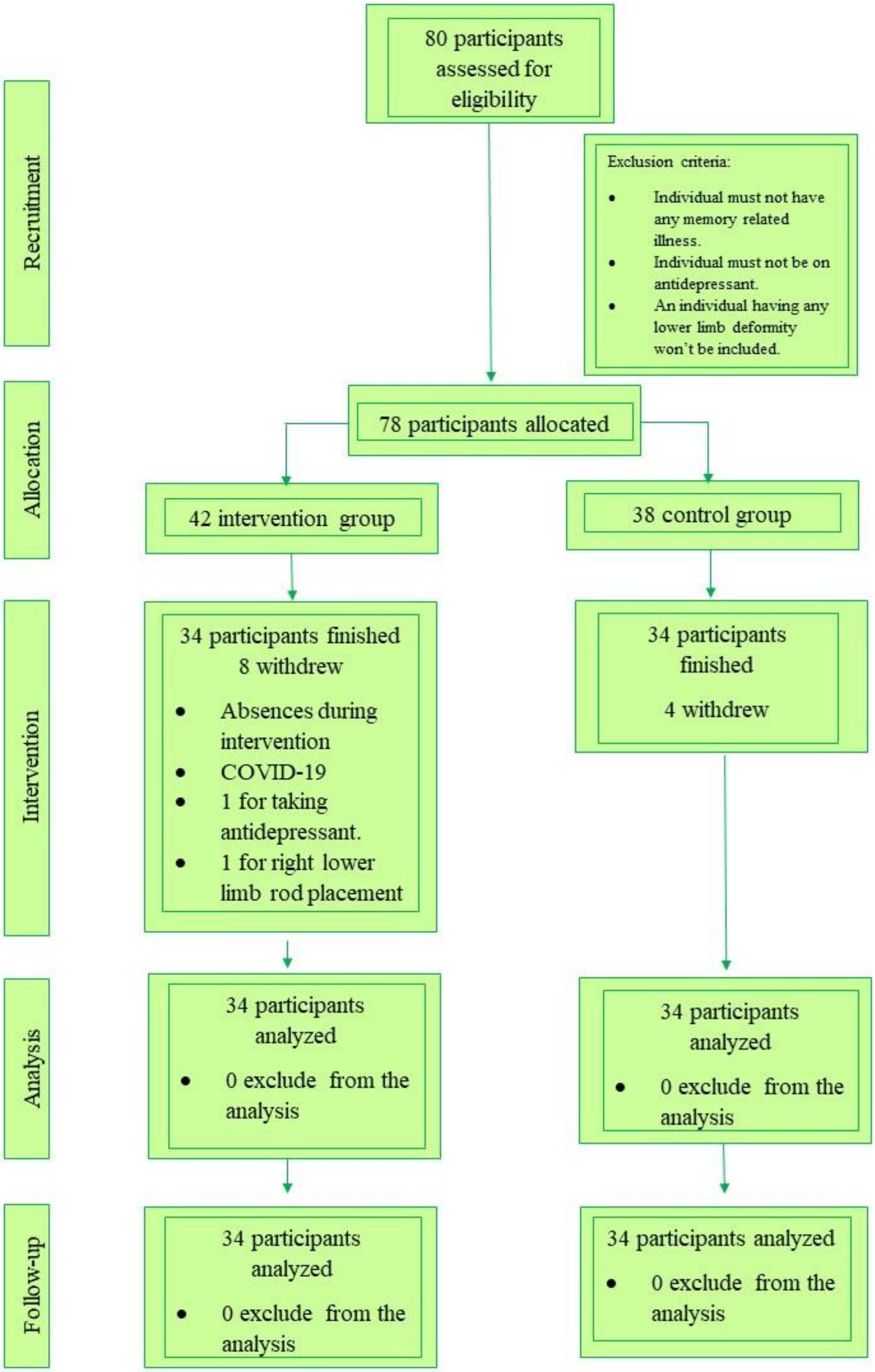

Figure 1. Flow chart for sample selection and analysis.

Table 1. Socioeconomic characteristics of study participants and self-report of mental health.

Variable		n (%) NE	n (%) TBE	p-value
Gender	Male	12(35.3)	26(76.5)	.001**
	Female	22(64.7)	8(23.5)	
Socioeconomic status	Upper middle	17(53.1)	23(67.6)	.422
	Middle	8(25.0)	7(20.6)	
	Lower middle	7(21.9)	4(11.8)	
Education	Intermediate	17(50.0)	17(50.0)	.927
	Bachelor	13(38.2	12(35.3)	
	Postgraduate	4(11.8)	5(14.7)	
Marital status	Single	25(73.5)	26(76.5)	.5
	Married	9(26.5)	8(23.5)	
Employment status	Student	25(73.5)	14(41.2)	.02*
	A homemaker	3(8.8)	2(5.9)	
	Employed	6(17.6)	17(50.0)	
	Unemployed	0	1(2.9)	
Family history of mental disorder	Yes	5(14.5)	8(23.5)	.269
	No	29(85.3)	26(76.5)	
Previous diagnosis of mental disorder	Yes	1(2.9)	2(5.9)	.5
	No	33(97.1)	32(94.1)	
Self-rated quality of sleep	Very poor	0	1(2.9)	.658
	Poor	6(17.6)	5(14.7)	
	Normal	17(50.0)	13(38.2)	
	Good	8(23.5)	12(35.3)	
	Very good	3(8.8)	3(8.8)	
Self-rated mental health	Poor	2(5.9)	1(2.9)	.5
	Average	16(47.1)	15(44.1)	
	Good	10(29.4)	7(20.6)	
	Excellent	6(17.6)	11(32.4)	
Medication	Yes	1(2.9)	2(5.9)	.5
	No	33(97.1)	32(94.1)	
Age (Mean ± SD)		34(24.85 ± 6.593)	34(25.41 ± 5.326)	.702

*Note. NE: Control group, TBE: Treadmill-based exercise group, * p < .05, ** p < .01).*

Study design, sampling and settings

The study was a prospective cohort and non-probability convenience sampling was used. Data were collected from various Physical Fitness Centres and Health Clubs for the exercise group, while participants for control group (NE) were selected based on the following inclusion criteria: i) a minimum higher secondary education, ii) active employment with professions incorporating less than recommended (< 150 minutes of moderate physical activity) hours as per guidelines (NHS, 2021). Sample size was calculated using effect size from following equation:

$$n = 2\frac{(Z\alpha + Z1 - \beta)2\sigma2,}{\Delta 2}$$

with $Z1 - \beta$ = 0.8 , Zα = 0.05, and Δ = 1.05 obtained from a previous study (Loprinzi et al., 2019) measuring the temporal effect of exercise on working memory, was used to obtain a total sample size of n = 32 that was inflated to n = 80 to account for non-respondent rate. Participants were divided into control/non-exercising (NE) group and treadmill-based exercise (TBE) group for a final number of n = 34 each group.

Data collection tool and procedure

Data on sociodemographic variables and a self-report of participant's mental health history including any previous history of psychiatric disorders, current medication and quality of sleep were obtained followed by the Goldberg test of intuitive decision making developed by (Goldberg, 2006), where the score is categorized as follows: > 6: Highly intuitive, 10-15: more intuitive than analytical, 5-0: analytical and rational, < 5: systematic rational approach of decision making. Treadmill based high-intensity exercise intervention was conducted for 30-40 mins continued for 3 times per week for a total of 34 sessions. High intensity treadmill based exercise followed the following protocol:

i. *5 minutes warm up.*
ii. *Running at 7 mph for 1 minutes followed 5.5 mph for 2 minutes X 5 for 15 minutes.*
iii. *1 minute recovery walk at intrinsic pace.*
iv. *Running at 10 mph for 1 minute, followed by 4 mph at 1 minutes X 5 for 8 minutes.*
v. *Cool down walk for 5 minutes.*

Statistical analysis

Data were analysed using IBM SPSS 21. Results were presented as mean ± SD. Paired t-test was done to determine the significant differences between NE and intervention groups after complete exercise duration. Participants with missing data (including loss of follow-up) were altogether excluded from the analysis. Mixed ANOVA was done to evaluate effects of exercise on intuitive decision making in both groups. Chi-square analysis was used to examine the difference of IDM sub-categories before and after intervention in both groups. IDM was categorized as systemic and rational for scores below 5, analytical and rational for scores between 5 and 9, more intuitive than analytical for scores between 10 and 15, and highly intuitive for scores 16 and beyond 16.

RESULTS

Sociodemographic and mental health characteristics of study participants

Descriptive statistics for the study participants at baseline are summarized in Table 1. The 2 groups were equally balanced for age. All 68 participants complete the full 34 session, treadmill-based exercise sessions. History of psychiatric diagnosis in the groups were rare, where participants in both groups had been previously diagnosed for anxiety, which was maintained with medication. Linear regression analysis was done to observe the effects of these confounders (Table 3 and 5).

Effect of treadmill-based exercise intervention on intuitive decision making

Previous studies have shown significant positive effects of physical exercise on various cognitive functions including attention span and memory (Leong et al., 2015). Therefore, we aimed to assess the impact of exercise on intuitive decision-making in daily life. A mixed-factor ANOVA on the combined data was initially performed to assess the difference and effect of treadmill-based exercise on IDM scores in both NEs and TBE group (Figure 2). Test of within subject effects revealed a significant interaction between time and groups (F = 10.35, $p < .01$, $\eta_p^2 = 0.136$). Since it was 2X2 mixed-factor ANOVA, Levene's test for equality of error variances, instead of Mauchy's test of sphericity was observed which revealed no significant differences of error between two time points in the sample (Pre F = 0.861, $p > .05$, post F = 0.105, $p > .05$). Given this finding, within subject effects assuming sphericity was also observed which revealed significant effect of time (F = 10.35, $p < .01$, $\eta_p^2 = 0.136$). Test of between-subject effects revealed significant effect of group (F = 13.52, $p < .001$, $\eta_p^2 = 0.17$).

We further delineated these effects using paired sample t-test (Table 2), which shows significant improvement in IDM scores in TBE group as compared to age-matched NE group (t = 1.22, df = 33, $p < .01$) with moderate effect size of 0.6 calculated using the formula:

$$d = \frac{\mid m1 - m2 \mid}{\sqrt{s1^2 + s2^2} - (2rs1s2)}$$

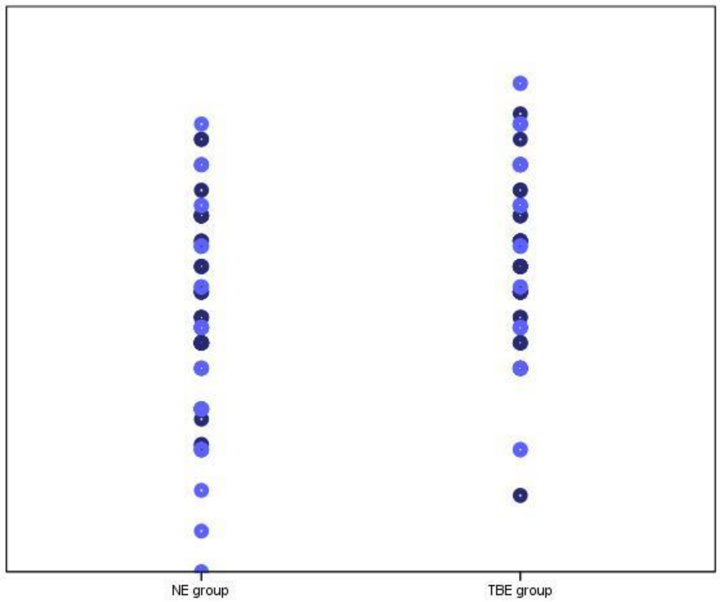

Figure 2. Scatter plots of the IDM scores in both NE and TBE group before (dark blue) and after (light blue) treadmill based exercise, built on SPSS version 21, using mixed-factor ANOVA.

Table 2. Paired sample test for IDM scores before and after treadmill-based exercise intervention.

Group	Mean ± SD (Pre-test)	Mean ± SD (Post-test)	*p*-value
NE	11.06 ± 3.08	10.38 ± 2.51	.23
TBE	11.68 ± 2.82	13.59 ± 2.36	.002**

*Note. NE: Control group, TBE: Treadmill-based exercise group, ** p < .01.*

Association of exercise with intuitive decision-making capability in study participants

Long-term exercise is associated with improved performance on various cognitive tasks including attention, executive function, and long-term memory (Winter et al., 2007). Recent studies have shown that even a single time of aerobic exercise can lead to an immediate improvement in declarative learning, attention, and memory (Winter et al., 2007), therefore we were interested study the association of exercise with intuitive decision-making capability. Table 3 shows the significant association of 30-40 mins of exercise continued for 3 times per week for a total of 34 sessions with IDM scores (B = 3.206, $p < .001$, CI = 2.25-4.386).

Table 3. Linear regression analysis of participant factors on IDM scores.

Variable	r^2	B	*p*-value	Confidence Interval
Treadmill based exercise	.308	3.206	.000**	2.25 – 4.386
Age	.011	0.052	.389	-0.068 – -0.171

*Note. r^2; correlation coefficient, B = beta coefficient, ** p < .01.*

Influence of socio-demographic characteristics and self-reported mental status on IDM

Many of the earlier studies through investigations have proved an association between socio-demographic variables and cognitive skills. Men as compared to women tend to get more cognitively affected with increasing age (Maylor et al., 2007). Similarly early life socioeconomic status (Bertola et al., 2021), marital status (Liu et al., 2020) and level of education (Lovden et al., 2020) have been shown to impact individual's cognitive abilities across their entire adult life span. Also, as significant group differences in gender and employment status were observed (Table 1), the sociodemographic characteristics were adjusted to observe the main effects on intervention ($F = 7.26$, $p < .01$) (Table 4).Also, it has been formerly proclaimed that patients with mental disorders such as major depressive disorder, schizophrenia etc have impaired cognitive skills (Hauenstein, 2003; Mihaljevic-Peles et al., 2019). Therefore, we were interested to observe whether mental disorder history in our participants influenced intuitive decision making or not. Table 4 shows no significant influence of mental health history of participants on intuitive decision-making scores.

Table 4. Covariate analysis of sociodemographic factors and self-rated mental status.

Variable	MS	F	η^2	*p*-value
Gender	0.162	0.019	0	.891
Marital Status	17.307	2.04	0.037	.159
Socioeconomic	28.77	3.392	0.06	.071
Education	13.415	1.582	0.029	.214
Employment	4.752	0.56	0.01	.457
Family history of mental disorder	19.308	2.276	0.041	.137
History of mental disorder	0.461	0.054	0.001	.817
Medication	0.254	0.03	0.001	.863
Self-rated quality of sleep	29.341	3.459	0.061	.068
Self-rated mental health	17.774	2.095	0.038	.154

Note. MS; Mean Square, η^2; eta square.

Difference of IDM categories between NE and intervention group before and after exercise

Decision-making incorporates capabilities such as systemic rational decision making, analytical and rational decision making, more intuitive than analytical decision making and strong intuitive decision making. After observing significant impact of exercise on overall intuitive decision making, we intended to study the difference of individual capabilities of intuitive decision making between members of interventional and NE group. Chi-square analysis shows that TBE group gained significantly stronger intuitive decision making capability after exercise intervention as compared to individuals in the NE group. Table 4 shows that out of the four defined IDM categories the number of individuals in category 1 (from 1 to 0) and category 2 (from 6 to 2) decreased, in category 3 no changes were observed while in category 4 the number increased (from 2 to 7) post-intervention.

DISCUSSION AND CONCLUSIONS

Intuition decision making is critical for quick integration of learned facts, concepts, procedures, and abstractions stored in the long-term memory (Patterson et al., 2013), required for the challenges of the contemporary world. Intuitive decision making capability in an individual is psychologically determined by internal and external determinants which incorporate metacognitive skills and environmental factors (Malewska, 2020), while the biological determinants of decision making capability include diet (Strang et al., 2017) and exercise (Wheeler et al., 2020). Beneficial effects of resistance exercise have been shown on cognitive function by enhancement of hippocampal synaptic plasticity-related molecules (Nichol et al., 2009), while structural changes related to strength training in white matter, grey matter, and putamen volume in the healthy adult brain (Palmer et al., 2013) are also evident.

Exercise has been shown to bring positive physiological changes and enhance mental functions, such as improvement in attention, memory, cognitive thinking, and decision making, (Wassenaar et al., 2019), however, the role of exercise in intuitive decision making is unrecognized. Therefore the current study assessed the impact of exercise on intuitive decision-making. A duration of 30-40 mins of exercise continued 3 times per week for a total of 34 sessions significantly enhanced the IDM scores (Table 2) which suggests that apart from different types of decisions making exercise can greatly affect intuitive decision-making. Since exercise has demonstrated improvement in cognitive function in healthy older adults (Kelly et al., 2014), a significant difference in the IDM scores post-exercise explains that it can be utilized for decision training purposes as well. Additionally, exercise also showed strong association with IDM scores (Table 3), which indicates that a routine based exercise can serve as a predictor of good intuitive decision making capability.

Since decision making is a complex task and involves social, psychological, environmental and biological factors, we aimed to study the influence of socio-demographic characteristics on intuitive decision making to exclude the possibility of confounders. Only employment status of the participants was significantly associated with IDM scores (Table 3). It is therefore, unravelled that socio-demographic characteristics of our study participants did not influence IDM scores. Similarly, association between self-reported mental health history and IDM scores was determined to exclude possible confounders which included family history of mental disorders, a self-evaluation of overall mental health, quality of sleep and use of any psychiatric medication. We observed no influence of self-reported parameters of mental health on IDM scores (Table 4). Intuition has previously been shown to be altered in psychiatric conditions (Remmers & Michalak, 2016; Srivastava & Grube, 2009), which suggests that mental disorders present with alterations in intuitive decision making, yet we found no association of self-reported mental health parameters primarily because of exclusion of diagnosed psychological disorder, thereby rendering the sample free of such confounders, however, data on quality of sleep and family history of mental disorders among other parameters of mental health was also not significantly correlated with IDM scores (Table 3), providing a conclusion that the sample remained unaffected from such confounders.

Intuitive decision making can take different forms where a person can show either rational, analytic, intuitive or a mixture of two decision making styles. We wanted to evaluate the difference of each group between NE and TBE to determine if improvement in IDM scores resulted from improvement in rational, analytical or intuitive decision making. Chi-square analysis showed that improvement in IDM scores was mainly contributed by increased number of people falling into intuitive decision makers category (Table 5). Exercise has been shown to improve cognitive functioning (Mandolesi et al., 2018), along with improvement in memory and executive functioning (Hoffmann et al., 2021), however, to the best of our knowledge there are no studies available to evaluate a direct association of exercise with intuitive decision making. Results from the current study provide a direct link of the effects of exercise on intuitive decision making.

Exercise is an important factor in determining physical and mental health. Cognitive health forms a crucial component of mental health and decision making is an integral part of cognitive functions. This study provides recommendation of incorporating exercise as part of the training programs of employees to enhance their intuitive decision making capacity which can serve to promote quick and healthy decision making, especially in technologically loaded domains where individuals mostly remain sedentary due to the nature of their work, thereby, also reducing the complications of a sedentary work style.

Table 5. Chi square analysis on difference in IDM categories before and after exercise intervention.

Groups	IDM Categories				Total	*p*-value
	Systemic rational decision making	Analytical and rational decision making	More intuitive than analytical decision making	Strong intuitive decision making		
Pre-NE	2	11	18	3	34	.37
Pre-TBE	1	6	25	2	34	
Post- NE	1	14	18	1	34	.001**
Post-TBE	0	2	25	7	34	

*Note. NE; Control group, TBE; Treadmill-based exercise group, ** p < .01.*

Strengths and limitations of the study

The study revealed a direct and moderate effect of high-intensity exercise on intuitive decision-making capability as compared to control group with active lifestyle in the absence of regular exercise. However, the convenience sampling, limits the generalizability of the results. A detailed analysis of mental health parameters like scores on anxiety, depression or stress could also have provided valuable insights on the impact of exercise in the presence of mental or psychological disorders, however, we excluded those to minimize confounders for an initial study of the effects of exercise on intuitive decision making in psychologically healthy subjects. For a better understanding of these effects in future studies, we aim to include QEEG analysis coupled with IDM scores before and after exercise to evaluate electrophysiological changes in the brain.

AUTHOR CONTRIBUTIONS

All co-authors have contributed to the published work defined as per and International Committee of Medical Journal Editors (ICMJE) guidelines in the table below and agree to its publication in Journal of Human Sport and Exercise. The manuscript follow rules set in the frame of the Council of Science Editors (CSE) and International Committee of Medical Journal Editors (ICMJE) guidelines for authorship.

Contribution	Explanation	*Contributing Authors*
Concept	The idea for research or article/hypothesis generation	*Meha Fatima Aftab, Asbah Faisal, Tatheer Fatima*
Design	Planning the methods to generate hypothesis	*Meha Fatima Aftab, Asbah Faisal, Mabel Waqar, Tatheer Fatima*
Supervision	Supervision and responsibility for the organisation and course of the project and the manuscript preparation	*Meha Fatima Aftab*
Resources	Supplying financial resources, equipment, space, and personnelvital to the project	*Meha Fatima Aftab*
Materials	Biological materials, reagents, referred patients	*Meha Fatima Aftab, Asbah Faisal, Mabel Waqar, Tatheer Fatima*
Data collection and/orprocessing	Responsibility for conducting experiments, management of patients, organising and reporting data	*Asbah Faisal, Mabel Waqar, Tatheer Fatima*
Analysis and/or interpretation	Responsibility for presentation and logical explanation of results	*Meha Fatima Aftab, Asbah Faisal, Mabel Waqar, Tatheer Fatima, Athar Khan*
Literature search	Responsibility for conducting literature search	*Meha Fatima Aftab, Asbah Faisal, Mabel Waqar, Tatheer Fatima*
Writing manuscript	Responsibility for creation of the entire or a substantial part ofthe manuscript	*Meha Fatima Aftab, Asbah Faisal, Mabel Waqar, Tatheer Fatima,*

		Athar Khan
Critical review	Reworking the final, before submission version of the manuscript for intellectual content, not just spelling and grammar check	*Meha Fatima Aftab, Athar Khan*
Other	*For novel contributions:*	*N/A*

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DISCLOSURE STATEMENT

No potential conflict of interest were reported by the authors.

DATA AVAILABILITY

The data is available from https://osf.io/rpbqc/?view_only=419ef1694ff941a5aba0d0a1665c14b4

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