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EFFECT OF FACE MASKS ON PHYSICAL PERFORMANCE IN EXPERIMENTAL TRIALS USING TREADMILL

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Abstract
The widespread use of face masks during the COVID-19 pandemic has prompted questions about their impact on individuals performing physically demanding tasks. This study investigated the effects of wearing face masks during simulated physically strenuous activities to address this concern. Physiological assessments were conducted using a heart rate monitor while participants walked on a motorized treadmill. Three workload levels (0%, 7.5%, and 15% of body weight) with the Borg CR10 scale used for workload classification. Results indicated significant differences in heart rate variability (HRV) parameters, particularly RMSSD and Total Power, when participants wore face masks during treadmill trials with no backpack load. Participants also reported higher perceived exertion while wearing masks across all workload levels. Notably, the increase in perceived exertion at higher workloads was less pronounced compared to the no-backpack condition. This study underscores the influence of face mask usage on physiological responses during physically demanding tasks and offers valuable insights into individuals' adaptation to mask-wearing in various work-related scenarios.
Key words: Face Mask, Heart Rate Variability, Borg CR10, RMSSD

1. INTRODUCTION

The use of face masks during physical activities has gained significant attention, particularly in light of their widespread adoption due to public health concerns. While face masks serve as vital tools in mitigating the spread of respiratory infections, their potential impact on physical performance, especially during demanding exercises, has been a subject of debate. This study seeks to contribute to this discourse by investigating the effects of wearing face masks on physical performance in experimental trials utilizing treadmill exercises.

Physical performance is a multifaceted concept, encompassing various parameters that include cardiovascular function and the ability to maintain endurance during physical exertion. In recent years, research has demonstrated that factors such as cultural and physiological differences may influence an individual's ability to perform demanding tasks (Ahmed et al, 2016). Furthermore, factors such as heart rate variability (HRV) have emerged as significant indicators of an individual's physiological response to exercise, with HRV being closely associated with exercise capacity and recovery (Aubert et al., 2003).

Studies have also highlighted the importance of monitoring HRV as a means of assessing physiological responses during exercise (Bae & Kwon, 2021). The analysis of HRV provides valuable insights into autonomic nervous system activity, which, in turn, can aid in understanding how factors such as face mask usage impact cardiovascular performance (Billman, 2013). Additionally, the perceived exertion experienced during physical activities is a key determinant of one's ability to sustain exercise effort (Borg, 1982). It is essential to examine how wearing face masks affects an individual's perceived exertion and, by extension, their overall exercise experience and performance.

Furthermore, the duration and magnitude of changes in HRV in response to various interventions can provide insights into an individual's adaptability to exercise and training (Buchheit & Mendez-Villanueva, 2014). As the global population continues to embrace face mask usage during physical

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activities, understanding the interplay between mask-wearing and exercise duration and intensity is crucial.
This study will investigate the impact of face masks on physical performance, focusing on metrics such as heart rate variability and perceived exertion. The findings will contribute to our understanding of the implications of face mask usage for individuals engaged in various levels of physical activity. In doing so, this research aims to provide valuable insights for individuals, athletes, and healthcare professionals as they make informed decisions regarding mask-wearing during exercise, ultimately promoting both public health and physical well-being.
To facilitate this investigation, the study will incorporate a comprehensive analysis of heart rate variability, informed by the latest research in the field (Camm et al., 1996; Carlos Torres-Herrera et al., 2023). By examining the physiological responses of individuals to face mask usage during treadmill-based exercise trials, this study aims to shed light on the relationship between mask-wearing and physical performance.
The exploration of this relationship is essential in the current global context, and the insights gained from this study have the potential to inform public health guidelines and recommendations for safe and effective mask usage during physical activities.

2. METHODOLOGY

During the initial phase of the study, a preliminary trial was conducted, leading to the development of an adapted experimental protocol. Subsequently, experimental trials were executed in accordance with the modified protocol. Following the trials, data analyses were performed and results were obtained.

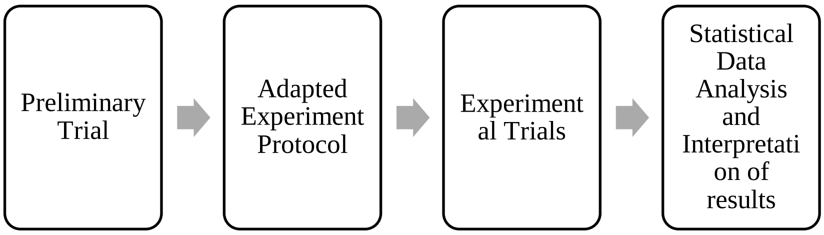

Figure 1: Methodology of study

2.1 Experimental Trials

The initial test was conducted at the Work Systems Design Laboratory in College of Engineering Trivandrum. The objective of the test was to help finalise the protocol adopted for the experimental trials. The initial test involved trials with different physical work simulations with different load levels and duration. After evaluating the results of the initial trials, the protocol finalised was treadmill walking at constant speed of 5kmph at zero inclination for a period of 20minutes followed by 20 minutes of recovery time. The work load levels were to be simulated by varying backpack load at 0% 7.5% and 15% of bodyweight. The experiment was to be done on healthy male college students between 20-25 years of age with BMI 19-25. The treadmill used for the experiment was Robust X1 supplied by M/s Probodyline©, Rajasthan, India. It is a motorized treadmill that is designed for heavy duty application. Face masks used in the study were similar to those evaluated by Li et al. (2005) in their study examining the effects of N95 and surgical facemasks on physiological responses. Baseline measurements of resting heart rate and HRV was recorded for a period of 10 minutes. Heart rate variability data were recorded in accordance with standard protocols, as mentioned in the works of Heine et al. (2017), Kim et al. (2009), and Pekdemir et al. (2004).

2.1.1 Participants

A total of 78 students of College of Engineering Trivandrum were contacted and briefed about the study. Sample size calculations were performed in accordance with established methods (Chow et al., 2017). 41 did not consent to participate. From the 37 who agreed to participate 4 subjects could not complete the trials and 2 sets of data could not be processed due to improper attachment of the belt. Total of 31 students completed the experimental trials. There were no cases of participant dropout attributable to medical reasons or adverse events. Participant summary are given in Table 1.

Industrial Engineering Journal
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The experimental trials were conducted in the laboratory during February-March 2023. The lab was well ventilated at a mean temperature 32.7 degrees Centigrade and Mean Relative Humidity of 63%.

Table 1: Participant Demographics

	Age (Years)	**Height (cm)**	**Weight (kg)**	**BMI (kg/m2)**
Mean	23.5	173.8	68.1	22.57
Standard Deviation	1.57	5.63	7.99	2.41
Range	21-26	162-180	60-77	20-25

2.2 Pre-Test Screening

Pre-test screening: The subjects Age, Height, Weight were recorded. Questions asked to ascertain whether subjects have any illness/medication/fatigue and to identify whether subjects have engaged in intense physical activity in the same day, time of having previous meal, if they have consumed alcohol, caffeine or nicotine etc. Participants who are healthy and fall within age group of 20-25 and with BMI 19-25 are requested to participate in the study and their consent taken after briefing about the procedure. The Heart Rate Monitor is attached to the subject after sanitizing the same. The participants were requested to walk on the tread mill for two minutes before the actual data collection so as to familiarize themselves with the experimental setup.

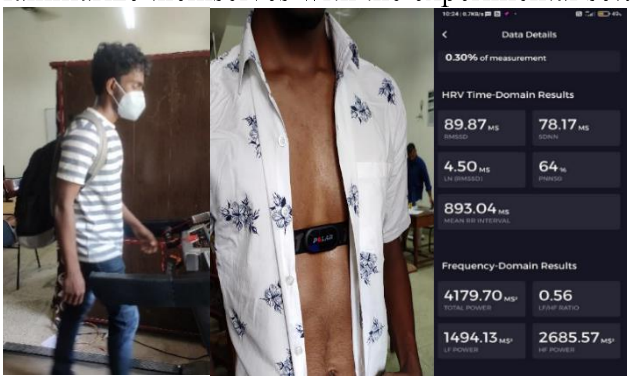

Figure 2 : Measurement of Transmitted Vibration

2.3 Measurement of Heart Rate Variability

Heart Rate Variability was measured using Polar H10 (Fig 2), heart rate monitor. The device uses a chest strap, the H10's electrodes detect the electrical signals produced by the heart and send this information to the device's processor. The processor then analyzes the data and uses it to calculate heart rate and HRV. The recorded data was aacquired via Bluetooth using Elite HRV an android application on a mobile phone. The data analysis was done using Microsoft Excel and IBM SPSS. During the test, the participant's heart rate parameters was continuously monitored, and ensured that it is within HR Max (220-age). Every 5 minutes into the test the participant's peripheral oxygen saturation (SpO2) was also measured in order to ensure that the SpO2 does not fall below 95%. The study analysed five Heart Rate parameters, Root Mean Squared Standard Difference (RMSSD), Standard Difference of NN interval (SDNN), Proportion of successive NN interval less than 50ms (PNN50), Low Frequency Power to High Frequency Power LF/HF ratio and Total Power (TP). The study incorporated HRV as a crucial indicator of physiological responses to exercise, in line with previous researches (Flatt et al., 2017; Javorka et al., 2002).

2.4 Measurement of perceived Exertion

Participants' perceived exertion during treadmill workouts was evaluated using established scales (Borg, 1982). For measuring the perceived exertion of the participants, Rating of Perceived Exertion (RPE) was used for finding the level of intensity in physical activity (Schaal 2013). Participants were asked to rate the perceived level of exertion on an ordinal scale from 0 to 10. (Borg CR10-Fig 3).

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0 Nothing at all
0.5 Extremely weak (just noticeable)
1 Very weak
2 Weak (light)
3 Moderate
4 Somewhat strong
5 Strong (heavy)
6
7 Very strong
8
9
10 Extremely strong (almost max)
• Maximal

Figure 3 : Borg CR (Borg 1982)

3. RESULTS AND DISCUSSIONS

3.1 Perceived Exertion

The means of the RPE collected from the participants based on BORG CR10 scale the means of the RPE ratings of the participants in comparison to the increased back pack load. Fig.4 indicates the trend of the RPE with change in back pack load and with and without using a facemask.

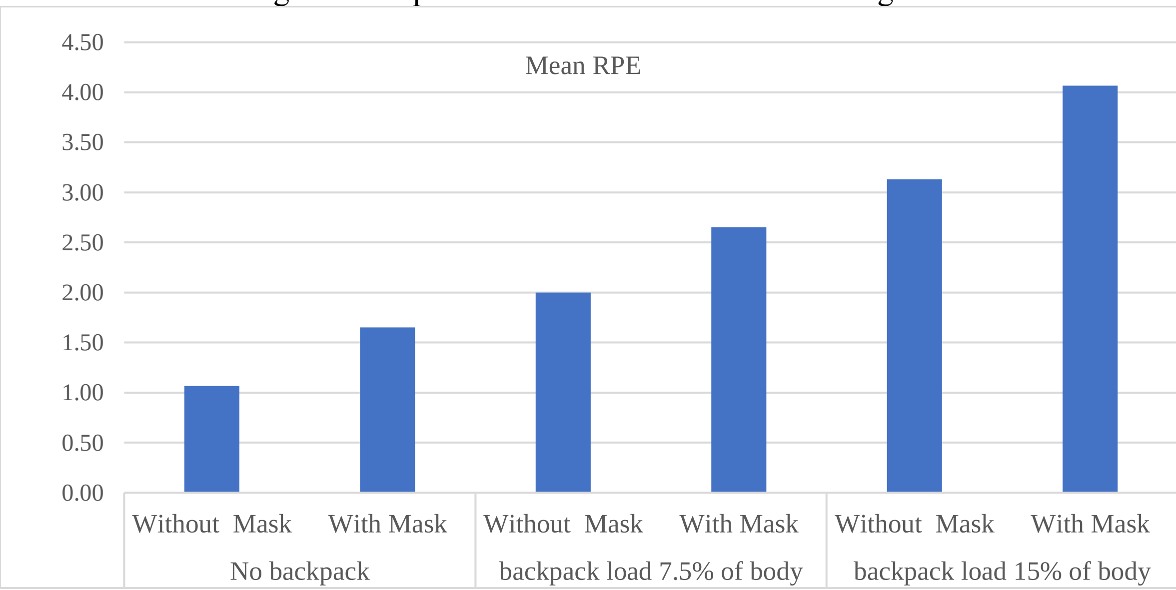

Figure 4 : Variation of Perceived exertion with load variation and mask usage

Table 2: RPE v/s Load v/s Mask

Back Pack Level	L0*		L1*		L2*	
Condition	Without Mask	With Mask	Without Mask	With Mask	Without Mask	With Mask
Mean Borg CR10 Rating	1.07	1.65	2.00	2.65	3.13	4.07

* L0: Zero backpack load, L1: backpack load 7.5% of bodyweight L2: backpack load 15% of bodyweight

During the experiment trial 40% of participants observed increase in RPE while performing the trial using facemask at both L0 and L1 load condition respectively. Whereas 93.33% participants observed increase in RPE while performing the trial wearing mask at L2 load condition. The mean RPE increased by 55.1%, 32.7% and 29.8% for the zero-backpack load (L0), 7.5% bodyweight backpack load (L1) and 15% bodyweight back pack load(L2) respectively. Though the participants observed a higher RPE at higher levels of the trial the increase in RPE is lesser at higher levels

4. STATISTICAL DATA ANALYSIS

Statistical analysis of HR parameters at different levels of workload level has been carried out with IBM SPSS software. The evaluation of potential fatigue was guided by methods established in previous research (Gershon et al., 2009; Goldstein, 2014). Shapiro-Wilks test (p>0.05) and observation of box plots showed that all HRV parameter values for the test were normally distributed for each category of experiment. The summary of the data is shared in Table 3. Standard error for skewness and kurtosis was 0.58 and 1.12 respectively. Since all 5 HR parameters are found to be normally distributed and the sample size is greater than 30, One-way ANOVA and paired t-test have been used for comparison of means.

Table 3 Test of normality of HRV Parameters

Load Level	HRV parameter	Mean	SD	Skewness	Std. Error	z	Kurtosis	Std. Error	z
L 0	RMSSD	9.36	4.51	0.38	0.58	0.66	0.31	1.12	0.28
L 1	RMSSD	8.53	4.56	0.61	0.58	1.05	0.36	1.12	0.32
L 2	RMSSD	10.84	4.71	0.25	0.58	0.43	0.18	1.12	0.16
L 0	SDNN	2.11	0.92	0.38	0.58	0.66	1.02	1.12	0.91
L 1	SDNN	3.07	1.02	0.26	0.58	0.45	1.12	1.12	1.00
L 2	SDNN	5.69	1.6	0.25	0.58	0.43	0.47	1.12	0.42
L 0	PNN50	0.47	0.18	0.27	0.58	0.47	1.33	1.12	1.19
L 1	PNN50	0.21	0.56	0.91	0.58	1.57	0.83	1.12	0.74
L 2	PNN50	0.33	0.89	0.57	0.58	0.98	0.61	1.12	0.54
L 0	TP	52.28	24.52	1.15	0.58	1.98	0.87	1.12	0.78
L 1	TP	49.84	34.45	1.04	0.58	1.79	1.03	1.12	0.92
L 2	TP	23.61	32.45	0.72	0.58	1.24	0.91	1.12	0.81
L 0	LF/HF	0.39	0.24	-0.17	0.58	-0.29	0.55	1.12	0.49
L 1	LF/HF	-0.62	1.02	0.15	0.58	0.26	0.51	1.12	0.46
L 2	LF/HF	-1.18	1.04	0.15	0.58	0.26	0.02	1.12	0.02

* L0: Zero backpack load, L1: backpack load 7.5% of bodyweight L2: backpack load 15% of bodyweight

4.1 One-way ANOVA.

To ascertain if there is any effect of level of backpack load on HRV parameter the data was analysed using one-way ANOVA.

The hypothesis for determining the effect of level of back pack load on HRV parameter:

H_0 : There is no significant difference in the means of the HRV Parameters across the three levels of backpack load level.

H_1 : There is significant difference in the means of the HRV Parameters across the three levels of backpack load level.

Table 4: Comparison of Means of RMSSD

δRMSSD	Sum of squares	df	Mean Square	F	Sig
Between Groups	67.185	2	33.593	3.211	0.04
Within Groups	439.432	90	10.463		
Total	506.617	92			

Table 5: Comparison of Means of Total Power

δTP	Sum of squares	df	Mean Square	F	Sig
Between Groups	67.185	2	33.593	3.211	0.04
Within Groups	439.432	90	10.463		
Total	506.617	92			

The analysis showed that the p-value in a one-way ANOVA (Analysis of Variance) is less than 0.05 as shown for the HR parameter RMSSD (Table 4) and Total Power (Table 5), it indicates that there is a statistically significant difference among the means of the groups being compared. In other words, there is evidence to suggest that at least one of the groups being compared has a different means compared to the other groups. Thus, the null hypothesis is rejected. Thus, there is statistical evidence that for at least one of the load level groups, the mean RMSSD and Total Power varies significantly from other groups at 95% confidence level.

4.2 Post Hoc Test

Since the group variances are homogeneous Fischer's Least Significant Difference LSD test is used for Post Hoc test. The post hoc test results are tabulated in Table 6 and Table 7.

Table 6: Comparison of Group Wise Means of RMSSD

(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.
L 0*	L 1*	2.51	1.18	0.039
	L 2*	2.66	1.18	0.029
L 1*	L 0*	-2.51	1.18	0.039
	L 2*	0.152	1.18	0.898
L 2*	L 0*	-2.66	1.18	0.029
	L 1*	-0.152	1.18	0.898

* L0: Zero backpack load, L1: backpack load 7.5% of bodyweight L2: backpack load 15% of bodyweight

Table 7: Comparison of means of Total Power

(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.
L 0*	L 1*	102.15	37.01	0.026
	L 2*	-95.89	37.01	0.031
L 1*	L 0*	-102.15	37.01	0.026
	L 2*	46.26	37.01	0.655
L 2*	L 0*	95.89	37.01	0.031
	L 1*	-46.26	37.01	0.655

* L0: Zero backpack load, L1: backpack load 7.5% of bodyweight L2: backpack load 15% of bodyweight

The mean difference of L1 and L2 are not significant, whereas mean difference of L0 and L1 and L0 and L2 is significant at 95% confidence level. Thus, the Post Hoc test provides statistical validation that the L0 has mean RMSSD and TP that is statistically significant from the other Load Levels.

4.3 Paired Sample T-Test

Paired t-test compares the differences in the means of pairs of data. So the test was used to compare the HRV parameters with mask and without mask.

The hypothesis for determining the effect of wearing of mask on HRV parameter:

H_0 : There is no significant difference in the HRV Parameters across the conditions while using mask and without it

H_1 : There is significant difference in the HRV Parameters across the conditions while using mask and without it

Table 8: Pair wise comparison of means of RMSSD

Paired Differences		Mean	SD	Std. Error Mean	T	df	Sig.
Pair 1	Exercise No Mask L0 - Exercise Mask L0	-2.7	3.81	0.7	-3.8	30	0.001
Pair 2	Exercise No Mask L1 - Exercise Mask L1	-0.1	1.92	0.35	-0.4	30	0.701
Pair 3	Exercise No Mask L2 - Exercise Mask L2	0.02	3.49	0.64	0.03	30	0.979

* L0: Zero backpack load, L1: backpack load 7.5% of bodyweight L2: backpack load 15% of bodyweight

Table 9: Pair wise comparison of means of Total Power

Paired Differences		Mean	SD	Std. Error Mean	T	df	Sig.
Pair 1	Exercise No Mask L0 - Exercise Mask L0	52.28	106.51	27.51	1.9	30	0.04
Pair 2	Exercise No Mask L1 - Exercise Mask L1	49.87	94.52	24.4	2.4	30	0.06
Pair 3	Exercise No Mask L2 - Exercise Mask L2	3.61	102.61	26.5	0.136	30	0.894

* L0: Zero backpack load, L1: backpack load 7.5% of bodyweight L2: backpack load 15% of bodyweight

For RMSSD (table 8) and Total Power (Table 9) the paired difference of the means of Pair 1 that compares TP at L0 with and without mask shows no significant difference with $p<0.05$. The paired differences of means of Pair 2 and Pair 3 that compares TP with and without mask at L 1 and L 2 exercise load respectively show $p>0.05$.

This indicates statistical evidence that there is significant effect of facemask usage on RMSSD while performing trials at L0 condition. However, there is insufficient statistical evidence to indicate significant paired difference of TP while performing at L1 and L2 levels of backpack load.

4. CONCLUSION

The physiological effect of usage of facemask while performing physically demanding task was analysed from the study. Though there was a change in HRV parameters while wearing a mask at exercise, statistically significant changes were observed in RMSSD and TP parameter at without backpack loads. At higher load levels significant changes were not observed. The perceived exertion increased with the usage of facemask. However, the rate of increase of RPE for the same load level was highest at no load and lower at higher level of load. This was substantiated by the quantitative tests. In line with our findings, Seibt et al. (2022) highlighted that face mask usage during submaximal bicycle ergometer tests affected physical performance and physiological responses. These findings provide valuable insights for public health guidelines, especially within the context of the COVID-19 pandemic and mask-wearing recommendations (World Health Organization, 2020). Our study also uncovered the respiratory challenges posed by face mask usage, with implications for perceived respiratory effort and physiological measurements. Steinhilber et al. (2023) identified limitations in evaluating protective face masks using open circuit spirometry systems, suggesting that mask-related biases could affect breathing pressure and effort. Additionally, Spang and Pieper (2021) observed tiny yet noticeable effects of respiratory masks on physiological and subjective measures under mental load. The findings of the present study is consistent with previous research highlighting the link between face mask usage and autonomic nervous system activity (Parati & Esler, 2012; Saboul et al., 2014). The observed changes in HRV parameters, such as the LF/HF ratio, suggest a potential impact on cardiac autonomic regulation. Similar results have been reported in the context of elite athletes, emphasizing the importance of HRV analysis in monitoring physiological responses (Plews et al., 2013). Our study however did not study the pulmonary function parameters such as V02max and also N95 Mask was included in the study. Further study on different types of face masks including pulmonary parameters has scope for further research.

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Furthermore, we would like to acknowledge the institutions and facilities that provided the necessary resources and support for this research, allowing us to carry out the simulated physically strenuous activities on the motorized treadmill with varying workload levels.

Finally, our appreciation goes out to the scientific community and the general public for their interest in this important research, which explores the impact of face mask usage in the context of public health and physical exertion. The valuable feedback and discussions from peers and colleagues have enriched our understanding of the subject matter.

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