

Effects of repetitive different jump pre-conditioning activities on post activity performance enhancement

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Purpose: The purpose of this study was to investigate effects of repetitive different jump pre-conditioning activities on post activity performance enhancement (PAPE).

Methods: Twenty-six male sports science faculty students who were physically active between the ages of 18-22 to participate in the study were divided into a squat jump group (SJG) ($n=14$, age 20.0 ± 1.3 year, height: 175.1 ± 6.7 cm, body weight: 71.9 ± 6.9 kg) and a countermovement jump group (CMJG) ($n=12$, age $20.1 \pm .9$ year, height: 175.3 ± 7.9 cm, body weight: 71.3 ± 8.2 kg). Squat jump (SJ) and countermovement jump (CMJ) tests were performed before the pre-conditioning activity, 4 min and 10 min after the pre-conditioning activity. SJG performed SJ and CMJG performed CMJ as the pre-conditioning activity with three reps. One-way repeated measures ANOVA was performed to determine the PAPE effect of pre-conditioning activities, SJ and CMJ on the variables flight time (FT), jump height (JH) and power (P) in SJ and CMJ tests after 4 min and 10 min. Significance level was taken as $P < .05$.

Results: Statistically significant differences were found as PAPE effect in SJ test FT, JH and P variables in the SJG at 4 min and 6 min after the pre-conditioning activity SJ ($F_{(2,12)} = 10.607$; $P = .002$, $\eta^2 = .639$ for FT; $F_{(2,12)} = 9.323$; $P = .004$, $\eta^2 = .608$ for JH and P). In CMJG, there were no statistically significant differences in PAPE effect in the CMJ test FT, JH, and P variables 4 min and 8 min after the pre-conditioning activity CMJ.

Conclusions: In conclusion, the time-dependent differences in SJ and CMJ performance of PAPE effects caused by repetitive pre-conditioning activities, SJ and CMJ, showed the importance of determining the exercises that will create a pre-conditioning and optimal rest periods for post-PAPE performance.

Keywords: Pre-conditioning activity, post activity performance enhancement, squat jump, counter-movement-jump

Introduction

Although one of the specific aims of warm-up is to provide a potentiation that will facilitate the related performance and increase work efficiency, post-activation potentiation (PAP) has been defined as the acute increase in peak force production that occurs during isometric contractions of muscles stimulated electrically or as a result of maximal voluntary contractions.¹ In other words, it is a theory that the intensity increases in a second contraction following the previous muscle activity.² Studies have shown that performing a pre-conditioning activity before the main activity causes an increase in athletes' performances such as sprinting and jumping.^{3,4}

A pre-conditioning activity usually requires maximum voluntary isometric contraction or maximum voluntary contraction.⁵ The performance of skeletal muscles in the organism is affected by the contraction history. The most obvious effect of the contraction history is fatigue, which negatively affects performance. However, since PAP can improve performance in contrast to fatigue, studies about PAP focus on the hypothesis that PAP can eliminate fatigue in the organism, positively affect strength development, and improve speed and power performance. PAP is a pre-conditioning, that is, an increase in muscle twitching and low-frequency tetanic force after contraction activity that will

create a pre-conditioning.¹

In terms of sports performance, PAP refers to the acute increase in muscle performance characteristics as a result of contraction histories. Therefore, the application of PAP to the athlete before the competition may be more beneficial than traditional warm-up techniques. In sports requiring explosive force, PAP training increases sportive performance.⁶ In order to have more detailed information on the performance of pre-conditioning effects, it is thought that further studies in which different exercise variables are applied on different populations are needed. Post-activity performance enhancement (PAPE) is defined as a "pre-conditioning" induced by voluntary muscle contractions, i.e. "pre-conditioning activities".⁷ McGowan et al.⁸ stated that pre-conditioning caused by targeted neuromuscular stimulation following an increase in body core temperature provides significant increases in exercise performance needed after the warm-up process. It is known that with this pre-conditioning, PAPE is particularly more clearly manifested and is associated with high performance results. It has also become important in sports such as athletics, which includes short and explosive activities such as sprinting, jumping, throwing, etc.⁹⁻¹² Plyometric exercises, which are used to improve the stretch-shortening cycle, are a widely used exercise model to produce PAPE. Plyometric exercises, routinely used to provide long-term

training effects in explosive strength development, are also used to acutely improve the performance of ballistic movements such as sprinting, jumping and throw. The studies^{13,14} reported that pre-conditioning with repeated hurdle jumps and depth jumps acutely increased sprint performance and vertical jump height statistically significantly.

Athletes are exposed to heavy loads depending on the maximal or near maximal exercises used during pre-conditioning applications. In this case, the performance-enhancing effects of different PAPE applications can last up to 6 hours.¹⁵ However, since an optimal rest interval is required after a pre-conditioning activity, if the rest interval is long, pre-conditioning effects are lost. If it is shortened, the expected efficiency cannot be obtained due to fatigue effects. Decreases in the force produced by each cross bridge during contractions can be seen due to insufficient rest time. Kilduff et al.¹⁶ found that statistically significant decreases in jump performance and power production occurred only 15 s after a pre-conditioning was established. In the same study, it was observed that the expected performance increase in the acute period was achieved when the athletes were given a rest time of 8 min. However, it was stated that the training levels of the athletes and their resistance to fatigue are also important in the potentiation-fatigue relationship. In Wilson et al.¹⁷ study, the optimal rest time after a pre-conditioning was found to be ≥ 2 min in untrained individuals, while it was found to be 3-7 min and 7-10 min in trained individuals and well-trained athletes. As can be seen from the above studies, there are many studies in the literature examining PAPE applied with various pre-conditioning activities such as sprinting, throwing and plyometric jumping. However, there is no study examining the effect of PAPE applied with pre-conditioning activities, squat jump (SJ) and countermovement jump (CMJ), at different durations. Therefore, the aim of this study was to investigate effects of repetitive different jump pre-conditioning activities on PAPE.

Methods

Participants

In this study, 30 male students aged 18-22 years, who were studying at the Faculty of Sport Sciences, participated voluntarily. The participants were divided into 2 groups as a squat jump group (SJG) with the pre-conditioning activity SJ and a countermovement jump group (CMJG) with pre-conditioning activity CMJ. Descriptive statistics of the groups are given in Table 1. Four students were excluded from the study due to data problems and the study was completed with 26 students. Participants were informed in detail about the purpose, content, importance, application, possible risks, and that they could freely discontinue the study at any time before starting the measurements and tests according to the procedures of the Declaration of Helsinki and signed an informed consent form. Each participant performed trial measurements and tests.

Research Design

Before starting the tests of the participants who signed the informed consent form before the study, the measurement and testing devices were calibrated and trial measurements and tests were performed for the participants to adapt to the laboratory conditions, anthropometric measurements and the SJ and CMJ test device. Three days after the trial measurements and tests, all participants participated to anthropometric measurements in the first session between 09.00 and 10.00. Squat jump (SJ) in SJG and countermovement jump (CMJ) in CMJG were tested as pre-tests in the second session between 10.00 and 12.00 am. Participants were dressed in shorts, t-shirts and sport shoes and performed a 10-min standard warm-up protocol consisting of light-paced running, flexibility and calisthenic movements before the tests. Each participant performed the jump test of his group 3 times with an interval of 30 s. Pre-conditioning activities (SJ for SJG and CMJ for CMJG) performed 1 min after the jump tests. The SJ test for SJG and CMJ test for CMJG were repeated 4 min and 10 min after the pre-conditioning activity to determine the resting time that produced the highest post-activation performance enhancement. The data of each jump test was recorded directly on the computer. The highest FT, JH, and also P of the highest JH obtained in 3 trials of each jump test were taken into statistical evaluation.

Height and Body Weight Measurements

Height was measured using a wall-mounted stadiometer (Holtain, UK) with an accuracy of .1mm. The measurement accuracy was checked by measuring the height between the ground and the head table of the stadiometer with the help of a standard aluminium flat bar of 60cm provided for standard height. Body weight was measured using an electronic laboratory scale (Seca, Vogel & Halke, Hamburg) with an accuracy of .1kg. Height and body weight were measured as recommended by Lohman et al.¹⁸

SJ and CMJ Tests

In the SJ and CMJ tests, a device (OptoJump™, Microgate, Bolzano/Italy) with two parallel bars (96 infrared light each), one of which functions as a transmitting unit and the other as a receiving unit, positioned .003 m above the ground, was used. When the infrared light was interrupted by the participant's foot during the jump, the timer was triggered and the time between the flight time and the ground contact time was recorded on the computer with a precision of 1 ms. Each participant was ready for the test with feet shoulder-width apart, eyes focused straight ahead, hands on waist, between the 2 bars of the device with infrared light. For the SJ test, as stated by Bosco and Komi¹⁹, participants came to the half-squat position with a knee angle of approximately 85°, where they felt a comfortable starting position by flexing the knees. In order to prevent pre-tension in the muscles before jumping, each participant made a vertical jump without making a downward movement after waiting for at least 2-3 s. For the CMJ test, each participant performed a vertical jump from the starting position as soon as possible after flexing the knees to approximately 85° knee angle as in the SJ

Table 1. Descriptive statistics of SJG (n=14) and CMJG (n= 12)

Variables	SJG (Mean $\pm$ SD)	CMJG (Mean $\pm$ SD)
Age (year)	20.0 $\pm$ 1.3	20.1 $\pm$.9
Height (cm)	175.1 $\pm$ 6.7	175.3 $\pm$ 7.9
Body Weight (kg)	71.9 $\pm$ 6.9	71.3 $\pm$ 8.2

Note: squat jump group (SJG), countermovement jump group (CMJG).

test. SJ test was performed 3 times with 30 s rest intervals before, 4 min after and 10 min after the pre-conditioning activity, SJ. With the same protocol, CMJ test was performed 3 times with 30 s rest intervals before, 4 min after and 10 min after the pre-conditioning activity, CMJ. The highest FT, JH, and also P of the highest JH obtained in 3 trials of each jump test were taken into statistical evaluation.

Pre-conditioning Activities

The pre-conditioning activities, SJ and CMJ, performed the same jump procedures as explained in the part of “SJ and CMJ Tests”. SJG performed 3 reps of SJ with 1 min rests as a pre-conditioning activity while CMJG performed 3 reps of CMJ with 1 min rests as a pre-conditioning activity.

Statistical Analyses

All statistical analyses were performed in Jamovi statistical program (2.3.28.0, Stats Open Now). Skewness and Kurtosis and Shapiro-Wilk analysis were used for a normal distribution and Mauchly's Sphericity Test for sphericity of all variables in SJG and CMJG. One-way ANOVA was performed in repeated measures to determine the PAPE effect on the FT, JH and P variables after 4 min and 10 min of the pre-conditioning activity. When the F statistics was significant for time-dependent changes, Bonferroni Test was used in pairwise comparisons to determine which variables caused the differences. Partial eta

squared (η^2) was calculated for the size of the trial effect. As stated by Richardson²⁰, partial η^2 was categorised as .01= small, .06= medium and .14= large effect. Statistical significance level was taken as $P < .05$.

Results

The results of the statistical analyses related to the time-dependent changes in the variables FT, JH and P of SJ test in SJG with the pre-conditioning activity, SJ and CMJ test in CMJG with the pre-conditioning activity, CMJ are given in Table 2, Table 3, Figure 1 and Figure 2. The data of the variables FT, JH and P of the SJ test in the SJG showed a normal distribution in the Skewness and Kurtosis and Shapiro-Wilk analyses. Except for the Skewness and Kurtosis of P_{pre} and P_{10min} variables based on P, all FT, JH and P variables of the CMJ test exhibited normal distribution in Skewness and Kurtosis and Shapiro-Wilk analyses. The sphericity assumptions of Mauchly's Sphericity Test were fulfilled for both groups. Repeated measures ANOVA was used in the statistical analyses of the time-dependent effects of the SJ for SJG and CMJ of CMJG for 4 min and 10 min. Table 2. showed the Mean $\pm$ SD and repeated measures ANOVA results for the variables FT, JH and P before, 4 min and 10 min after the pre-conditioning activity, SJ.

Table 2. Time-dependent effects of SJ on FT, JH and P variables in SJG (n= 14)

Variables	Mean $\pm$ SD	F	P	η^2	Paired Comparisons
FT (s)	FT _{pre} .520 $\pm$.039	10.607	.002	.639	FT _{4min} – FT _{pre} FT _{4min} – FT _{10min}
	FT _{4min} .540 $\pm$.045				
	FT _{10min} .523 $\pm$.049				
JH (cm)	JH _{pre} 33.3 $\pm$ 5.0	9.323	.004	.608	SJ _{4min} – SJ _{pre} SJ _{4min} – SJ _{10min}
	JH _{4min} 36.0 $\pm$ 6.1				
	JH _{10min} 33.8 $\pm$ 6.3				
P (W)	P _{pre} 3222.1 $\pm$ 475.5	9.323	.004	.608	P _{4min} – P _{pre} P _{4min} – P _{10min}
	P _{4min} 3387.7 $\pm$ 522.1				
	P _{10min} 3254.2 $\pm$ 511.4				

Note: flight time (FT), jump height (JH) and power (P).

Statistically significant differences were found in the FT, JH and P variables of the SJ test as PAPE effects of the SJ for 4 min and 10 min ($F_{(2;12)} = 10.607$; $P = .002$, $\eta^2 = .639$ for FT; $F_{(2;12)} = 9.323$; $P = .004$, $\eta^2 = .608$ for JH and P). As a result of Bonferroni Post Hoc test, it was stated that there were significant differences ($P < .05$) between the pre-test and the post-test after 4 min, the post-test after 4 min and the post-test after 10 min of all 3 variables.

Figure 1. showed the Mean $\pm$ SD. There were significant differences ($P < .05$) between the pre-test and the post-test after 4 min, the post-test after 4 min and the post-test after 10 min of all 3 variables. All 3 variables showed statistically significant ($P < .05$) increases in the post-test after 4 min, while they displayed statistically significant ($P < .05$) decreases in the post-test after 10 min compared to the test performed 4 min later.

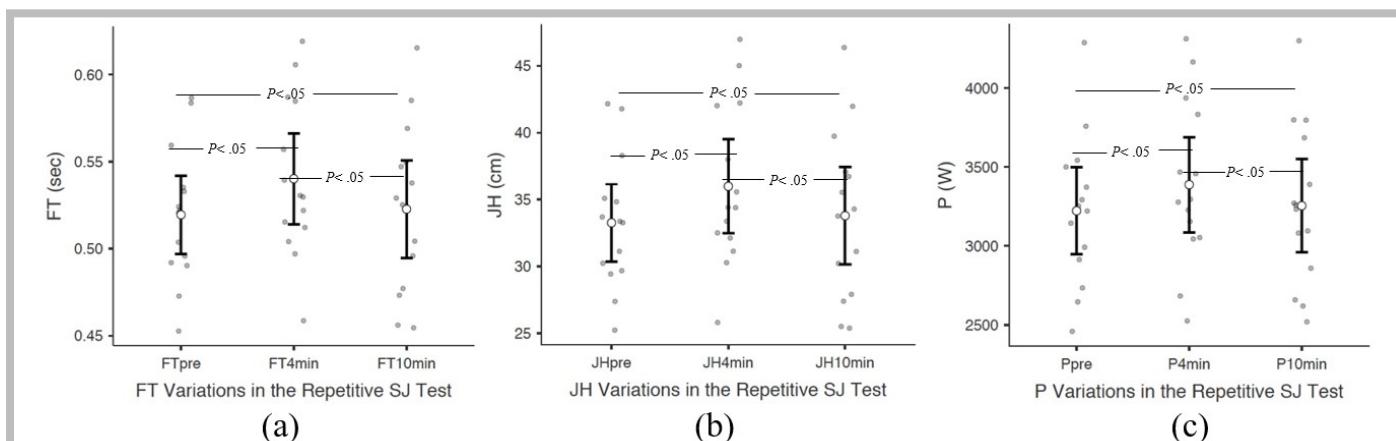


Figure 1. Time-dependent effects of SJ on FT (a), JH (b), P (c) parameters in SJG (n= 14).

Table 3. displayed the Mean $\pm$ SD and repeated measures ANOVA results for the variables FT, JH and P before, 4 min and 10 min after the pre-conditioning activity, CMJ. Although there were slight increases in FT, JH and P variables 4 min and

10 min after the pre-conditioning activity, CMJ as an effect of PAPE, these increases were not statistically significant ($F_{(2;10)} = 1.915$; $P = .198$, $\eta^2 = .277$ for FT; $F_{(2;10)} = 1.797$; $P = .215$, $\eta^2 = .264$ for JH and P).

Table 3. Time-dependent effects of CMJ on FT, JH and P variables in CMJG (n= 12)

Variables		Mean $\pm$ SD	F	P	η^2
FT (s)	FT _{pre}	.537 $\pm$.028	1.915	.198	.277
	FT _{4min}	.545 $\pm$.032			
	FT _{10min}	.546 $\pm$.037			
JH (cm)	JH _{pre}	35.4 $\pm$ 3.6	1.797	.215	.264
	JH _{4min}	36.5 $\pm$ 4.2			
	JH _{10min}	36.6 $\pm$ 4.9			
P (W)	P _{pre}	3323.7 $\pm$ 365.0	1.797	.215	.264
	P _{4min}	3393.5 $\pm$ 437.3			
	P _{10min}	3399.0 $\pm$ 432.5			

Note: flight time (FT), jump height (JH) and power (P).

Figure 2. displayed the Mean $\pm$ SD. Although there were slight increases in FT, JH and P variables 4 min and 10 min after

the pre-conditioning activity, CMJ as an effect of PAPE, these increases were not statistically significant.

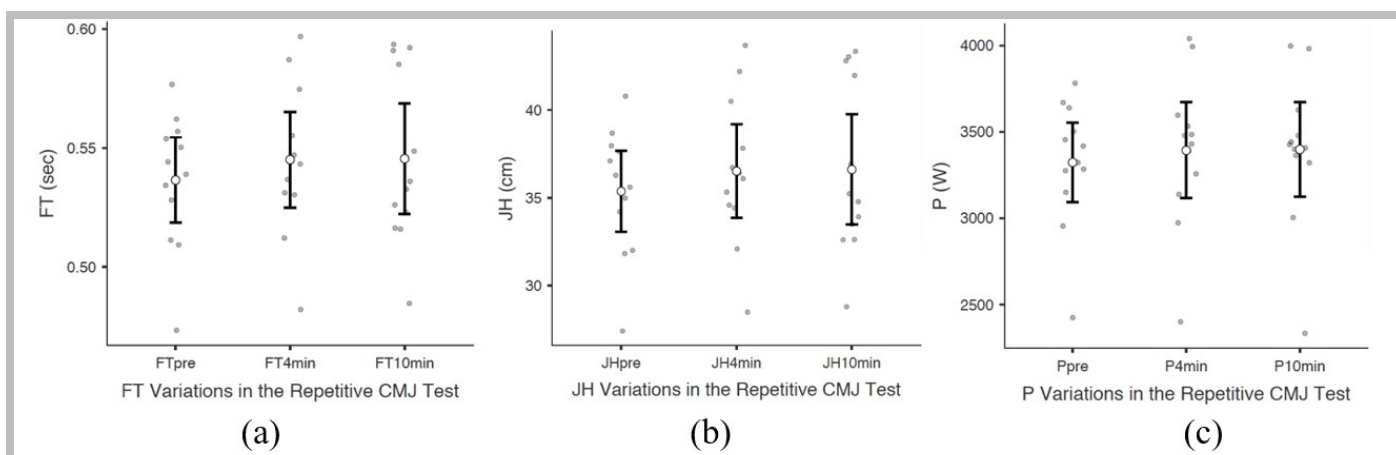


Figure 2. Time-dependent effects of CMJ on FT (a) , JH (b) , P (c) parameters in CMJG (n= 12).

Discussion

The aim of this study was to investigate the effects of repetitive pre-conditioning activities SJ and CMJ on post activity performance enhancement. Previous studies^{3,21,22} showed that a pre-conditioning activity before the main activity causes an increase in athletes' performances such as sprinting and jumping. In the present study, an acute statistically significant increase was found in the SJ performance of the SJG at 4 min after the pre-conditioning activity SJ, while no statistically significant difference was found in the CMJ performance of the CMJG performing the pre-conditioning activity CMJ.

Titton and Franchini²³ examined the effect of squat exercise on CMJ performance in foot players at 4 different intensities (6 reps with 40%, 4 reps with 60%, 3 reps with 80% and 1 RM 100%) and after 4 different recovery times (1 min, 3 min, 5 min and 10 min). They found that 1 min rest after squat exercise applied as a pre-conditioning activity was statistically better than 3 min, 5min and 10 min rest even if the exercise intensity changed ($P < .05$). In contrast to the present study, Jensen and Ebben²⁴ examined the PAPE effects on CMJ performance after 10 s, 1 min, 2 min, 3 min and 4 min of 5 RM squats in athletes and found a statistically significant decrease in CMJ performance after these 5 time points ($P < .05$). Suchomel et al.²⁵ stated a

PAPE effect on both SJ and CMJ performances after an intensive pre-conditioning activity.

As other results of the present study, a statistically significant increase was found in the FT, JH and G variables of SJG at 4 min after the pre-conditioning activity SJ, while a statistically significant decrease was found at 10 min. No statistically significant difference was found in FT, JH and G variables of CMJ at 4 min in CMJG with the pre-conditioning activity CMJ. In addition, a statistically significant decrease was found in the SJ performance of SJG at 10 min after a pre-conditioning activity, while no statistically significant difference was found in CMJG. Lowery et al.²⁶ determined the vertical jump power after 0, 2, 4, 8 and 12 min of low-intensity (56%), moderate-intensity (70%) and high-intensity (93%) squat exercise warm-ups and found that it was statistically significantly higher than the pre-test value after 4 and 8 min. In the studies of Kilduff et al.¹⁶ and Jo et al.²⁷ on trained athletes, it was stated that PAP was optimised at 8-12 min and 5-10 min. This showed that the rate of isometric force development increased significantly at 4.5-12.5 min recovery [28]. Chattong et al.²⁹ reported that there was no time-dependent statistical difference in terms of JH, G, strength and velocity variables related to CMJ at 1st, 2nd, 3rd, 5th, 10th and 15th min after squat exercises with different pre-conditioning activities. Villalon-Gasch et al.³⁰ found that because an optimal rest period

is required after each pre-conditioning activity, if the rest period is prolonged, the pre-conditioning activity effects are lost, and if it is shortened, the expected PAPE is not seen due to fatigue. In the results of the present study, the decrease in all variables of SJG at the 10th min supported this study. The fatigue was caused by a decrease in Ca^{++} sensitivity due to insufficient rest or a decrease in the force produced by each crossbridge during contractions.^{6,31,32} Several physiological mechanisms were also found as components of PAP, such as increased phosphorylation of myosin light chains, increased work with high motor excitation and increased muscle stiffness.³²⁻³⁴ These activations were more intense in type II muscle fibres used in high-intensity and short-duration movements such as vertical jumping.³⁵ In addition, the pennation angle of active muscles in SJ and CMJ affected jump performance.^{6,36,37} Mahlfeld et al.³⁶ observed that the pennation angle of the vastus lateralis muscle decreases over time and is related to vertical jump power in trained individuals. In the studies³⁸⁻⁴⁰, it was determined that PAP and related PAPE were higher in highly trained individuals than in recreationally trained individuals. The reason for the difference in the results in the present study may be due to the fact that the participants were recreationally active individuals and their neuromuscular characteristics, fatigue status, training background, as well as the physiological mechanisms of PAP were lower than those of highly trained individuals.

Practical Applications

In training science, various training methods are used to improve the performance of athletes. This study was conducted considering that jumping movements are a widely used training method to improve athletic performance, since jumping pre-conditioning activities increase the strength of athletes. As a result of this study on the effect of repeated pre-conditioning activities, SJ and CMJ on post-activity performance enhancement, it was concluded that the pre-conditioning activity SJ would be an important reference for maximising the performance of athletes in sports that involve explosive power, especially when performed 4 and 8 minutes before the competition.

Conclusions

In conclusion, the time-dependent differences in SJ and CMJ performance of PAPE effects caused by repetitive pre-conditioning activities, SJ and CMJ showed the importance of determining the exercises that will create pre-conditioning and optimal rest periods for post-PAPE performance.

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Ethical Committee approval

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Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Topic

Sport Science.

Conflicts of interest

The authors have no conflicts of interest to declare.

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Declaration if used ChatGPT

We don't used ChatGPT.

Author-s contribution

Conceptualization, M.K., Y.Y., A.B.T., and E.A.; methodology, M.K., Y.Y., A.B.T., and E.A.; software, A.B.T.; validation, Y.Y.; formal analysis, M.K.; investigation, A.B.T., and E.A.; resources, Y.Y., A.B.T., and E.A.; data curation, M.K., and A.B.T.; writing—original draft preparation, M.K., Y.Y., A.B.T. and E.A.; writing—review and editing, M.K.; visualization, M.K. and A.B.T.; supervision, M.K.; project administration, A.B.T. All authors have read and agreed to the published version of the manuscript.

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