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Improving spatio-temporal stride parameters, lower limb muscles activity and race walkers' records after 12-weeks special exercises using rhythmic auditory

Mejora de los parámetros espaciotemporales de pasos, actividad muscular de las extremidades inferiores y registros de marchadores después de ejercicios especiales de 12 semanas usando audición rítmica

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ABSTRACT

This study aims to know the effect of 12-weeks of special exercises using rhythmic auditory to improve spatio-temporal stride parameters (STSP), lower limb muscles activity (LLMA), and 10000m racewalking time (RT). The parameters of STSP are stride length (SL), step cadence (SC), and center-of-mass velocity (CMV). The research sample included twelve racewalkers, and they were divided into two groups (control group and experimental group, six in each). STSP was measured using a Sony camera at a speed of 50 frames/sec for analyzing 25-samples for each racewalker in the 10000m racewalking. LLMA was measured using EMG. In addition, we applied the 10000m test to measure RT. Rhythmic auditory was used to regulate the step rhythm in seven special exercises and the essential part of the training. The steps rhythm was divided into three levels: the 1st slow auditory rhythm, the 2nd comfortable auditory rhythm, and the 3rd fast auditory rhythm. From our findings, there is a significant difference in the post-test for SC, CMV, LLMA, and RT, favoring the experimental group, where P.04<.05, η2=.732 for SC, P.038<.05, η2=.485 for CMV, P.015<.05, η2=.333 for LLMA, and P.044<.05, η2=.483 for RT. While there is no significant difference in the post-test for SL, where P.264>.05. In addition, there is a significant improvement between groups favoring the experimental group as ROC=1.62,5.76,7.48,33.9, and 7.03% for SL, SC, CMV, LLMA, and RT respectively. Comparisons showed that the post-test achieved greater improvement with a large effect in STSP, LLMA, and RT compared to the pre-test that achieved a small effect. Therefore, the rhythmic auditory in the training has a beneficial role in improving spatio-temporal stride parameters, lower limb muscles activity and racewalkers' records.

KEYWORDS

Race walking; stride length; cadence; special exercises; rhythmic auditory; EMG.

RESUMEN

El objetivo de este estudio fue investigar el efecto de 12 semanas de ejercicio con audición rítmica en la mejora de los parámetros de zancada espaciotemporal (STSP), actividad muscular de las extremidades inferiores (LLMA) y tiempo de marcha de 10.000 metros (RT). Los parámetros de los pasos espacio-temporales de la zancada son la longitud de la zancada (SL), el ritmo de la zancada (SC) y la velocidad del centro de masa (CMV). La muestra de la investigación estuvo conformada por doce marchadores, quienes fueron divididos en dos grupos (un grupo de control y un grupo experimental, con seis en cada grupo). Los STSP se midieron con una cámara Sony a 50 fotogramas/seg para analizar 25 muestras de cada marchador de 10.000 metros. LLMA se midió mediante un electromiograma. Además, aplicamos la prueba de 10.000 m para medir el RT. La audición rítmica se utilizó para regular el ritmo del paso en siete ejercicios especiales y la parte central del entrenamiento. El ritmo de los pasos se dividió en tres niveles: el primer ritmo auditivo lento, el segundo ritmo auditivo cómodo y el tercero ritmo auditivo rápido. De nuestros hallazgos existe una diferencia significativa en el post-test para SC, CMV, LLMA y RT, a favor del grupo experimental, donde $P.04 < .05$, $\eta2 = .732$ para SC, $P.038 < .05$, $\eta2 = .485$ para CMV, $P.015 < .05$, $\eta2 = .333$ para LLMA y $P.044 < .05$, $\eta2 = .483$ para RT. Sin embargo, no hay diferencia significativa en el post test para SL, donde $P.264 > .05$. Además, hay una mejora significativa entre los grupos a favor del grupo experimental: ROC = 1.62, 5.76, 7.48, 33.9 y 7.03 % para SL, SC, CMV, LLMA y RT respectivamente. Las comparaciones mostraron que el post-test logró una mayor mejora con un efecto significativo en STSP, LLMA y RT en comparación con el pre-test que logró un efecto pequeño. Por lo tanto, la audición rítmica en el entrenamiento tiene un papel útil en la mejora de los parámetros de paso espacio-temporales, la actividad muscular de las extremidades inferiores y los registros de la marcha.

PALABRAS CLAVE

Marcha atlética; longitud de zancada; cadencia; ejercicios especiales; audición rítmica; EMG.

1. INTRODUCTION

Racewalking is a rhythmic and dynamic endurance event within the sport of Athletics (Milic et al., 2020)(Megahed et al., 2021), it has complex technical and higher requirements for physical function and competitive ability (Ma, 2021). Where participants in the race are asked to finish the race distance in the shortest amount of time possible while adhering to the IAAF rules 230.1(non-loss of contact, and straightness knee from touch down to mid-stance) (Rules IAAF Competition, 2017). So, coaches use special exercises to develop their athletes' movement skills and their speed during training (Hanley et al., 2017). Mechanically, success in a racewalk depends primarily on racewalking speed (Hanley, 2014). The two main variables of racewalking speed are cadence and step length. The optimal relationship must be considered between these two components when training on them. By increasing cadence and stride length simultaneously, or increasing one variable while maintaining the other, or increasing one of them by a greater amount while decreasing the other. The racewalkers must find for themselves the adequate walking tempo, concerning the optimal proportion of the cadence and stride length (Raković et al., 2011). It's not surprising that articles on biomechanics and coaching have focused on these two variables. The literature that deals with the study of the men racewalkers stated that step length (Mean ±SD) from 1.11 ±0.09 to 1.25 ±.05m, and step cadence (Mean ±SD) from 3.08 ±.28 to 3.34 ±.12Hz (Cairns, 1984; Hanley, 2014; Hanley et al., 2017; Hoga-Miura et al., 2017; Lafortune et al., 1989; J Padulo, 2015; Vinogradova & Sovenko, 2020).

The recent literature focused on studying the role of sound in sport for a better understanding of how auditory information guides actions (Crasta et al., 2018; Schaffert et al., 2019, 2020). The literature has corroborated the relevance of auditory information in that appropriate use of auditory information can significantly contribute to improved performance in different sports (Schaffert et al., 2019; Sors et al., 2015). Sound has also been shown to ameliorate the performance when used as a model indicating to the performer the perfect performance to follow (Agostini et al., 2004). Rhythmic auditory (RA) during physical activity has been considered as a means of motivating individuals to engage in repetitive, and long-term activities (Patania et al., 2020) as racewalking. RA has been described in the literature as " attracts attention, regulates or modifies mood, increases productivity, increases arousal, promotes rhythmic movement, and encourages higher performance" (Thakare et al., 2017). It has been proved that RA is capable of eliciting changes in behavior, i.e., a particular change in brain function can encourage persons to increase their exercise obligation and participation in races (Altenmüller & Schlaug, 2012). Additionally, RA is efficacious in decreasing fatigue and enhancing the motor system's efficiency, where music is associated with rhythm (Bigliassi et al., 2017; Patania et al., 2020). Neurophysiological studies have established that the central nervous system is extremely sensitive to musical signals and its response is various, including conduct, muscle activation, and practical functions (Altenmüller & Schlaug, 2013; Thaut & Abiru, 2010). Another literature showed that auditory information is relevant and important for motor rehabilitation. It is possible to improve the rehabilitation protocols of patients with motor disturbance by using auditory cues. The method used by these researchers is known as RA stimulation, which consists of walking in synchronization with an RA. Improvements have been largely observed in Spatio-temporal parameters of gait (Agostini et al., 2020; Thaut et al., 1993).

Through the first author's experience as a former racewalker and current coach, as well as through his follow-up to national and world racewalking competitions, we noticed a fluctuation in the technical level of participants in national competitions, a short stride length and/or a slow cadence. It is noted from the previously mentioned literature RA played an important role in muscles activation and step cadence control for athletes. However, to our knowledge, no studies have been conducted on the effect of special exercises using RA to improve Spatio-temporal stride parameters and lower limb muscle activity of racewalkers. In the present paper, we aim to study the effect of 12-weeks special exercises using RA to improve Spatio-temporal stride parameters, lower limb muscle activity and 10000m record of racewalkers.

2. METHODS

2.1. Participants

The research sample included twelve racewalkers were selected from Al-Ahly and ghazel El-mahalla Clubs. They were divided into two groups with six racewalkers each group; a control group, with (Mean ±SD, CV) age of (18.7 ±.8 years, 4.37 %), height (169.7 ±2.73 cm, 1.61 %), weight (61.3 ±4.84 kg, 7.90 %), HRrest (60.7 ±4.27 r/min,7.05 %), inspiratory capacity (3.52 ±.15, 4.29 %) ; and an experimental group, with (Mean ±SD, CV) age of (18.8 ±.75 years, 4 %), height (170 ±3.39 cm, 1.99 %), weight (62.5 ±5.32 kg,8.51 %), HRrest (60.5 ±5.09 r/min,8.41 %), and inspiratory capacity (3.47 ±.16 l, 4.53 %). CV ranged from 1.61 to 8.51 %, which is less than 30 %, which indicates the homogeneity of the research sample. The following inclusion criteria were met; all participants (A) were ranked at the national's championships, (B) had skill with more than four years of training, (c) none had any musculoskeletal injuries, (D) continued their regular training routines. Before engagement, all participants were told about the study's objectives, procedures, and provided their voluntary assent. This study was approved by the Ethics committee of the computers and information faculty, Mansoura University (code: 202109005).

2.2. Experimental design

In the present study, we used the method of pre-test (taken at the beginning) and post-test (taken at the end, after 12-weeks). The study was broken up into four phases. Phase 1 represented a preparation study which lasted one week that was carried out to check for the reliability of the tools, the devices and measures used in this research. Also, this phase was used to guide the participants to conduct the experiment familiarization process (i.e. the utilization of treadmill, EMG, and RA) in a climate-controlled. After that, phase 2 consisted of 2-days for pre-testing, phase 3 took 12-weeks of concurrent training and phase 4 consisted of 2-days for post-testing.

Independent variables: 12-weeks special exercises using RA. Dependent variables: Spatio-temporal stride parameters (STSP), lower limb muscles activity (LLMA) uv.min, and 10000m racewalking time (RT) min. The parameters of STSP are stride length (SL) m, step cadence (SC) step/min, and center of mass velocity (CMV) m/sec. The stride length (SL) is defined and calculated from the distance between a specific instant on the gait cycle on one foot to the equivalent instant on the same foot (a stride = two steps). Step cadence (SC) refers to the frequency of steps occurring during the walking action (Hanley, 2014).

2.3. Procedures

Pre-testing occurred on two different days separated by a minimum of 48-hours. Before each testing session, they were asked to avoid intense exercise for the past 24-hours and arrive at the location of the test rested (> 8-hours of adequate sleep time, no muscle soreness and strong testing motivation) (Li et al., 2021). The first day presented measurements of the STSP and RT test, while the second day included EMG measurements. Post-tests followed the same protocol as the pre-tests.

Measurements and Tests

In the present study, we used two measurements: STSP which was held at the Ghazl El-Mahalla Club, and LLMA which was held at the Tanta sport medicine center using EMG. These measurements had been done as follows:

A. Measurement of the STSP

One stationary digital camcorder (Sony at a speed of 50 frames/sec) was placed from field interior on a 1.5 m high tripod standing, far 8.5 m from the racewalkers, and located perpendicular for the participant's frontal plane. The field of visual motion was 6 m wide, this allows to record consecutive two-stride lengths for the racewalkers. The camera was placed to racewalkers photography approximately 150 m from the start line to be far from the curvature of the walking track and the absence of obstacles in view of it. Reflective markers were placed on the joints of the racewalkers and 25-samples (1-sample each 400 m) were taken for each racewalker in the 10000m racewalking. The film sequences were analyzed using (Pro-Trainer) motion analysis software for extracting the following STSP: SL (m), SC (step/sec), CMV (m/sec). Figure 1 shows the camera position in the field and its dimensions with distances of 25-samples.

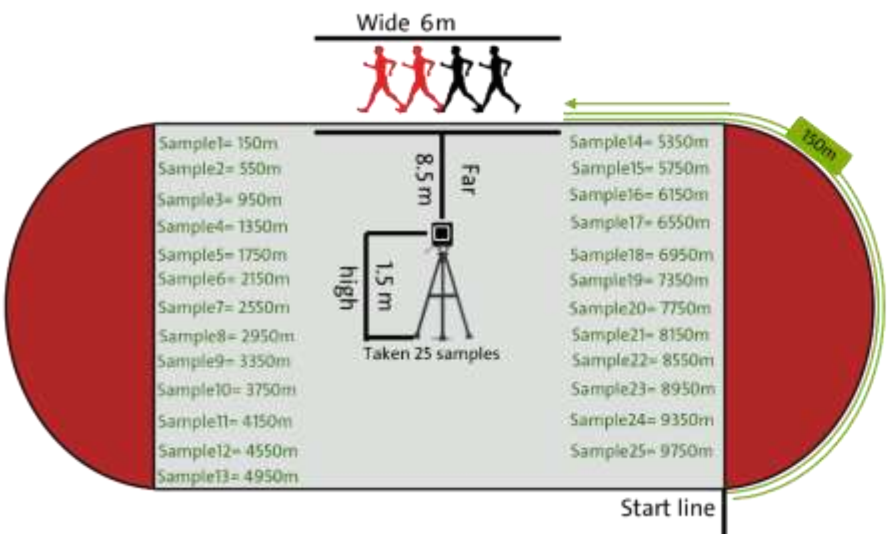

Figure 1. Digital camcorder position and its dimensions with distances of 25-samples

B. Measurement of LLMA

EMG electrodes were used to collect LLMA for eight muscles simultaneously during racewalking. Before the electrode placement, the participant's skin was shaved and cleaned with alcohol. The eight muscles as the literature reported are gluteus maximus(GMax), gluteus medius(GMed), biceps femoris(BF), rectus femoris (RF), vastus lateralis (VL), tibialis anterior (TA), gastrocnemius (GA), and soleus (SO) (Hanley, 2014; Hanley & Bissas, 2013; Murray et al., 1983; Schmitz & Norberg, 2019). Figure 2 shows the eight muscles used in this study.

Figure 2. The eight lower limb muscles

Participants carried out 10000m racewalking on the treadmill with the same speed in measurement A. EMG was collected during two phases (2150 m and 8150 m) for the 10000m racewalking. The literature reported that there was a high correlation between over-ground and treadmill walking equally to r=0.93 (Riley et al., 2008). The treadmill was calibrated and checked before and after each test, according to the instructions of the manufacturer (Johnny Padulo et al., 2014). Each participant performed a 10 min warm-up followed by 5 min of dynamic muscular stretching before test execution.

This study also included a 10000m test that was used to measure RT, which was held at the Ghazl El-Mahalla Club at the same time as STSP measurement to compare between the experimental group and the control group in the pre-test and post-test. We used stopwatches according to IAAF rules (Rules IAAF Competition, 2017).

Training protocol

Participants have been given training during the special preparation period that was carried out for 12-weeks, 4-days per week, a total of 48-training sessions took place. The experimental group performed training on Saturday, Sunday, Tuesday, Thursday using RA, while the control group performed on Monday, Wednesday, Friday, Saturday without using RA. The Participants started training with a warm-up consisting of 5-10 min of easy running followed by dynamic flexibility and muscular stretching drills (5-10 min). After that, the essential part plus special exercises 75-90 min were executed, followed by an easy 5min cool-down of easy walking, then again 5-10min of easy stretching. The details of the essential part of the training program are given for the experimental group in Table 1. The Participants who were allocated to the control group took the training prepared as the experimental group, but without RA on the same times as the previously mentioned days.

Table 1. The essential part of the training schedule (12-weeks) for the experimental group.

Week	Saturday		Sunday		Tuesday		Thursday	
1	4-5x2000m	@ **FAR** with 2:00 breaks	8000m	steady tempo	6x800m	@ **FAR** with 2:00 breaks	13000–16000m	**@ SAR, HR (140:150) r/m**
2	3×3000m		10000m		4x1200m		13000–16000m	
3	2×5000m		8000m	acceleration	6x800m		13000–16000m	
4	4-5×2000m		8000m		4x1200m		13000–16000m	
5	3×3000m		10000m		6x800m		13000–16000m	
6	2×5000m		10000m		4x1200m		13000–16000m	
7	4-5×2000m		8000m		6x800m		13000–16000m	
8	3×3000m		8000m		4x1200m		13000–16000m	
9	2×5000m		10000m		6x800m		13000–16000m	
10	4-5×2000m		10000m		4x1200m		13000–16000m	
11	3×3000m		8000m		6x800m		13000–16000m	
12	**6x800m**		**8000m**	**easy**	**Rest**		**13000–16000m**	

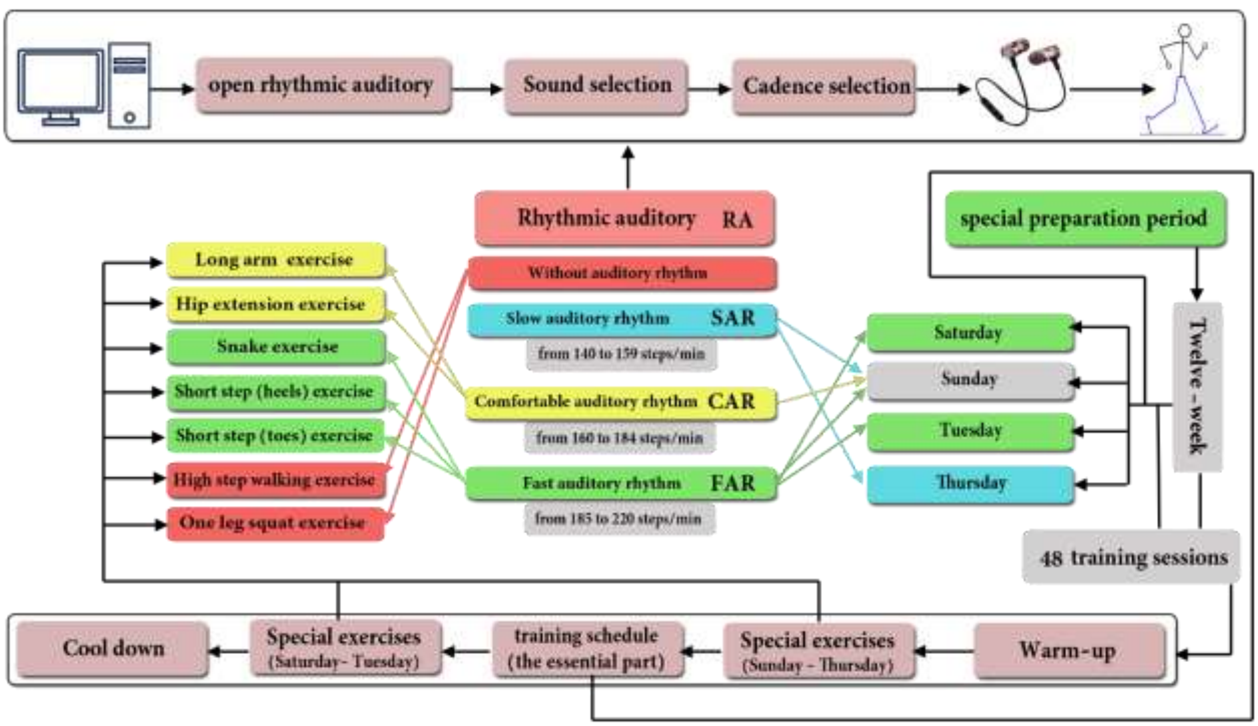

Figure 3. The framework of the proposed training program using RA procedures

During the 12-week training in Table 1, RA was used to regulate the step rhythm in the essential part of the program to the participants. The steps rhythm was divided into three levels of cadence; the 1st was slow auditory rhythm (SAR) from 140 to 159 steps/min, the 2nd was comfortable auditory rhythm (CAR) from 160 to 184 steps/min, and the 3rd was fast auditory rhythm (FAR) from 185 to 220 steps/min. On Saturdays and Tuesdays, we used a FAR, and it was gradually distributed over the weeks. We used FAR in (1st, 2nd and 3rd) weeks from 185 to 195 steps/min, (4th, 5th and 6th) weeks from 195 to 200 steps/min, (7th, 8th and 9th) weeks from 200 to 205 steps/min and (10th,11th and 12th) weeks from 200 to 220 steps/min, with an appropriate stride length. On Sundays, we used the three levels of cadence (SAR: CAR: FAR) respectively, distributed over the distances for (2000: 3000: 3000) m for (3rd and 4th) weeks, (2000: 4000: 4000) m for (5th and 6th) weeks, (0: 3000: 5000) m for (7th and 8th) weeks, (0: 4000: 6000) m for (9th and 10th) weeks and (0: 2000: 6000) m for 11th week, with an appropriate SL. In the 1st and 2nd weeks on Sundays, we used a CAR, but with longer strides than usual. On Thursdays, we used a SAR, with longer strides than usual. The training program procedures for only the experimental group are shown in Figure 3.

Special exercises

In the present paper, we used 7 exercises to develop movements relevant to racewalking (Drake, 2003). The exercises were used during the training program every week, on the 1st and 3rd days after the warm-up and before the essential part. While these exercises were used on the 2nd and 4th days after the essential part of the training program and before the cool down.

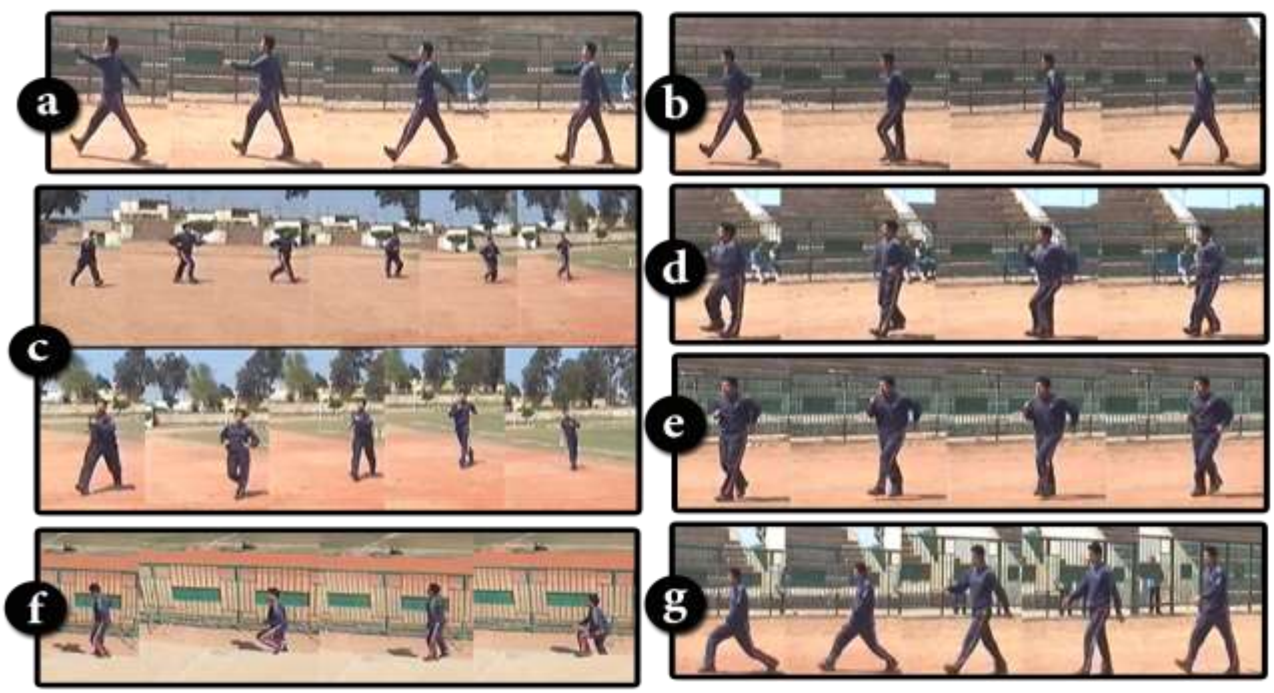

Figure 4. The special exercises: (a) Long arm, (b) Hip extension, (c) Snake, (d) Short step (heels), (e) Short step (toes), (f) High step walking, and (g) One leg squat.

These exercises (repeated three times for 50 minutes in total for each exercise) were: (a) the participant walks and holds arms at his side, one in front and the other behind the body, keeping both arms straight and his hands flat with palms back, using CAR with longer strides than usual (See Figure 4-a). (b) The participant walks with normal technique, except places the hands behind the back, using CAR with longer strides than usual (See Figure 4-b). (c) The participant walks in an imaginary snake or S-shaped line performed using FAR with slightly shorter strides than usual (See Figure 4-c). (d) The participant walks quickly, with a stride of only six inches, focusing on rising toes continually, using FAR (See Figure 4-d). (e) The participant walks quickly, with a stride of no more than six inches, focusing on rising heels continually, as high off the ground as possible, using FAR (See Figure 4-e). (f) The participant walks with one foot on a high (curb/runway), pushes up, and moves with the other foot forward and returns vice versa, without RA (See Figure 4-f). (g) The participant walks in two steps normal walking, he squats down in the third step for three seconds without going past the knee the front of the toes, without RA (See Figure 4-g). Notably, participants in (a), (b), (c), (d) exercises performed the racewalking technique.

2.4. Statistical analysis

The statistical analysis included: 1) Descriptive statistics; mean (M), standard deviation (SD), coefficient of variation (CV). 2) Rate of Change (ROC) = ($\frac{(post-test)-(pre-test)}{(pre-test)} * 100$). 3) Significant differences between groups were identified in pre-test and post-test. 4) (Partial) Eta Squared ($\eta 2$) was used to compare between groups in pre- and post-test. 5) Effect sizes were calculated as $\eta 2$ values and determined as small ≥ .01, medium ≥ .06, large ≥ .14(Maher et al., 2013). The criterion alpha level was set at $p \leq .05$, and all statistical analyses were performed using the statistical software SPSS (Version 26).

3. RESULTS

Multiple computer-aided software systems have been relied upon to handle and analyze the outputs accurately and with high efficiency. Among the technology that depends on using computers, is Pro-Trainer motion analysis software to manipulate video data for extracting the STSP parameters. Also, SPSS software technology is used which had a significant role in interpreting the results and their derivatives using computers.

In this section, we present the major findings according to the explained procedures and statistical analysis in the previous section. Table 2 lists t-test, η2, ES, and ROC to compare between the experimental group and control group in pre-test and post-test for STSP, LLMA, and RT.

Table 2. T-test, η2, ES, and ROC between both groups in pre-test and post-test for STSP, LLMA, and RT

Variable	Group		Mean ±SD	T	P	η2	ES	ROC %	
								Control group	Experimental group
SL	Pre-test	Control	2.24 ±.062	.443	.234	.019	small	.34	1.62
		Experimental	2.25 ±.040						
	Post-test	Control	2.25 ±.037	1.485	.264	.181	large		
		Experimental	2.29 ±.058						
SC	Pre-test	Control	178.2 ±1.4	.697	.336	.046	small	2.47	5.76
		Experimental	178.9 ±1.9						
	Post-test	Control	182.6 ±.87	5.232	.040<	.732	large		
		Experimental	189.2 ±2.9						
CMV	Pre-test	Control	3.32 ±.079	.706	.644	.047	small	2.83	7.48
		Experimental	3.35 ±.084						
	Post-test	Control	3.42 ±.057	3.071	.038<	.485	large		
		Experimental	3.61 ±.140						
LLMA	Pre-test	Control	1223.9 ±163	.223	.992	.010	small	15.2	33.9
		Experimental	1245.4 ±171						
	Post-test	Control	1409.9 ±97	2.232	.015<	.333	large		
		Experimental	1666.9 ±265						
RT	Pre-test	Control	50.14 ±1.2	- .652	.600	.023	small	-2.94	-7.03
		Experimental	49.72 ±1.2						
	Post-test	Control	48.67 ±.83	- 3.027	.044<	.483	large		
		Experimental	46.23 ±1.8						

The effect of training on STSP, LLMA and RT are shown as follows:

Effect of Training on STSP

There is no significant difference between the control group and experimental group in the pre-test, where t=.443, P .234 > .05 for SL, t=.697, P .336 > .05 for SC, and t=.706, P .644 > .05 for CMV.

While there is a significant difference between the control group and experimental group in the post-test for SC, CMV favoring experimental group, where t=5.232, P .040< .05, η2= .732, ES= large for SC, and t=3.071, P .038 < .05, η2= .485, ES= large for CMV. And there is no significant difference between the control group and experimental group in the post-test for SL, where t=1.485, P .264 > .05.

In addition, there is a significant improvement in STSP parameters between both groups, favoring the experimental group as ROC= 1.62, 5.76, 7.48 % for SL, SC, and CMV, respectively.

Effect of Training on LLMA

There is no significant difference between the control group and experimental group in the pre-test, where t=.223, P .992 > .05. While there is a significant difference between the control group and experimental group in the post-test favoring experimental group, where t=2.232, P .015< .05, $\eta 2$= .333, ES= large. Further, there is a significant improvement between both groups, favoring the experimental group as ROC= 33.9% compared to 15.2% in the control group.

Effect of Training on RT

There is no significant difference between the control group and the experimental group in the pre-test**,** where t=.652, P .600 > .05. While there is a significant difference between the control group and the experimental group in the post-test favoring the experimental group, where t=3.027, P .044< .05, $\eta 2$= .483, ES= large. There is a significant improvement between both groups favoring the experimental group as ROC= 7.03% compared to 2.94% in the control group.

Figure 5 shows the (Mean ±SD, Min, and Max) of SL (2.25 ±.040, 2.19 ,2.31) m, SC (178.9 ±1.9, 170, 200) step/min, and CMV (3.35 ±.084, 3.28, 3.76) m/sec in pre-test. While the (Mean ±SD, Min, and Max) in post-test of SL is (2.29 ±.058, 2.26 ,2.34) m, SC (189.2 ±2.9, 190, 214) step/min, and CMV (3.61 ±.140, 3.47, 4.01) m/sec.

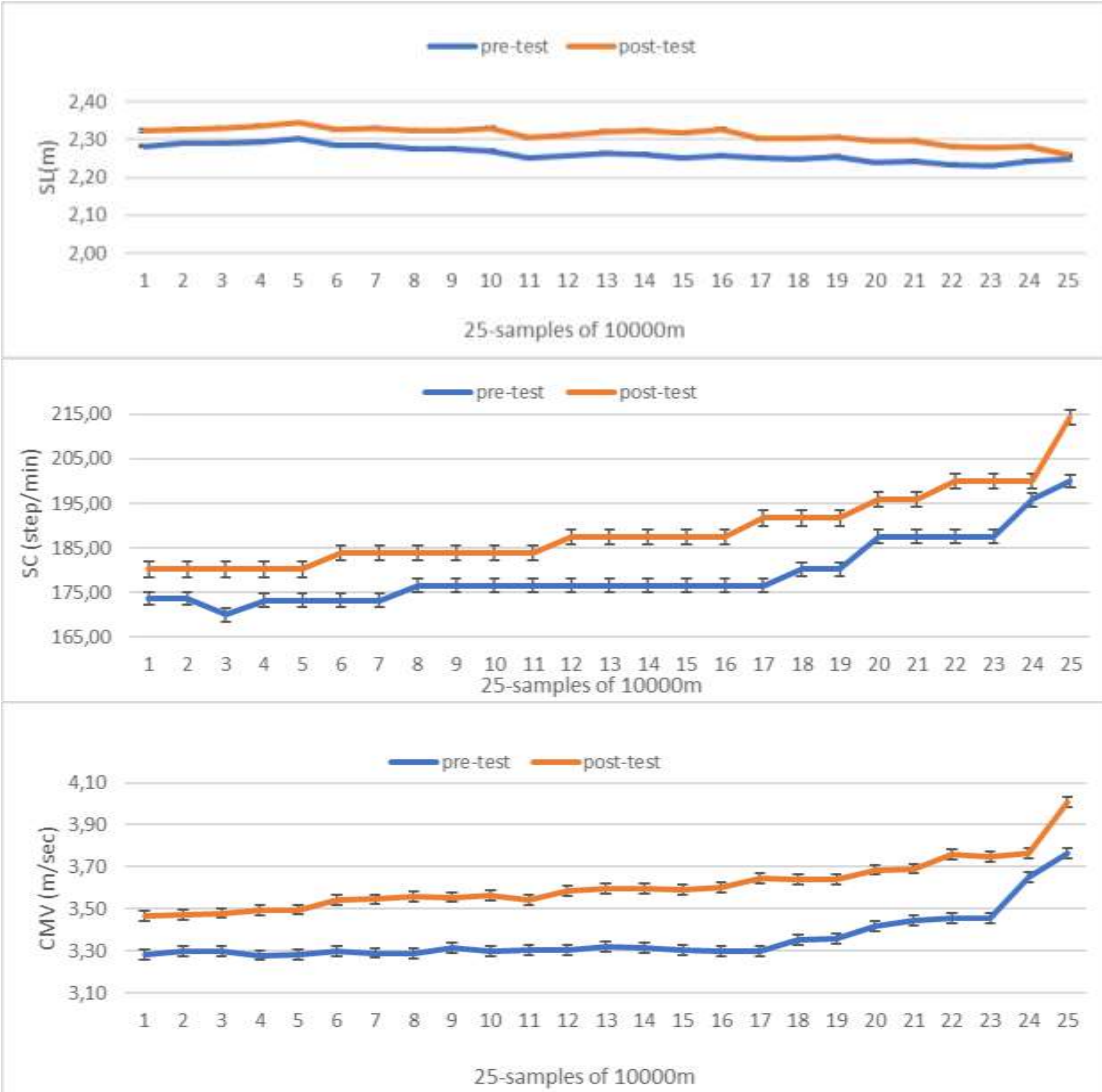

Figure 5. Mean, min, and max of STSP (SL, SC and CMV) in 25-samples of the experimental group in the pre-test and post-test by the 10000 m racewalking.

Table 3 shows that there is a significant difference between the pre- and post-test for the experimental group in the LLMA during the 1st phase at 2150 m favoring the post-test, where t-values are ranged of (4.088: 9.498), P-values < 0.05. Also, there is a significant difference during the 2nd phase at 8150 m favoring the post-test, where t-values are ranged of (4.127: 7.764), P values < 0.05. We noted that EMG was improved for all muscles favoring post-test with fixed contribution ratio in BF (L), while contribution ratio was increased in (Gmax, Gmed, BF, RF, VL, TA) (R) and VL(L) and contribution ratio was decreased in (GA, SO) (R) and (Gmax, Gmed, RF, TA, GA, SO)

(L). In Table 3, green color is assigned for fixed contribution ratio, yellow color for increased contribution ratio, and red color for decreased contribution ratio.

Table 3. Differences between Pre-test and Post-test in each muscle of LLMA for the experimental group (N= 6).

Limb	Muscles	1st phase at 2150m				2nd phase at 8150m				Contribution ratio (%)	
		Pre-test Speed. Avg =11.8 km/h	Post-test Speed. Avg = 12.3 km/h	Paired Differences		Pre-test Speed. Avg = 12.6 km/h	Post-test Speed. Avg = 13.3 km/h	Paired Differences			
		Mean ±SD	Mean ±SD	t	p-value	Mean ±SD	Mean ±SD	t	p-value	Pre-test	Post-test
Right (R)	Gmax	88.53 ±11.4	131.09 ±25.0	6.073	.002<	140.92 ±27.2	181.80 ±28.7	6.318	.001<	9.2%	9.4%
	Gmed	70.90 ±12.5	103.68 ±17.3	9.498	.000<	109.84 ±16.5	149.98 ±22.8	5.125	.004<	7.3%	7.6%
	BF	54.02 ±10.6	80.48 ±21.27	5.453	.003<	81.62 ±13.6	107.54 ±14.8	4.805	.005<	5.4%	5.6%
	RF	53.69 ±14.1	70.24 ±23.7	5.586	.003<	69.72 ±10.9	101.53 ±15.7	6.526	.001<	5.0%	5.2%
	VL	51.58 ±9.91	64.02 ±15.2	4.088	.009<	50.14 ±7.9	91.17 ±7.4	7.764	.001<	4.1%	4.7%
	TA	54.89 ±13.1	91.45 ±24.9	6.945	.001<	92.17 ±12.2	127.26 ±19.9	4.922	.004<	5.9%	6.6%
	GA	51.67 ±7.17	64.89 ±13.0	4.237	.008<	68.60 ±10.4	91.23 ±14.4	4.590	.006<	4.8%	4.7%
	SO	64.59 ±9.0	84.01 ±14.5	5.750	.002<	82.27 ±10.0	108.83 ±19.9	4.250	.008<	5.9%	5.8%
Left (L)	Gmax	96.40 ±13.7	134.27 ±22.0	7.792	.001<	148.92 ±19.5	183.10 ±26.4	4.420	.007<	9.8%	9.5%
	Gmed	79.18 ±10.8	108.46 ±15.5	7.680	.001<	128.96 ±17.7	146.37 ±19.7	4.654	.006<	8.4%	7.6%
	BF	57.21 ±9.05	78.33 ±14.90	6.758	.001<	84.95 ±14.6	111.10 ±17.1	5.035	.004<	5.7%	5.7%
	RF	57.28 ±6.82	69.95 ±10.80	4.631	.006<	84.62 ±10.0	106.29 ±13.2	4.486	.006<	5.7%	5.3%
	VL	53.47 ±6.53	67.00 ±9.63	5.729	.002<	67.72 ±10.4	99.84 ±14.7	6.964	.001<	4.9%	5.0%
	TA	67.74 ±8.7	87.92 ±8.48	7.565	.001<	103.07 ±11.9	132.06 ±21.3	4.175	.009<	6.9%	6.6%
	GA	50.81 ±5.2	64.64 ±9.9	4.371	.007<	65.60 ±10.1	89.68 ±10.7	5.732	.002<	4.7%	4.6%
	SO	62.84 ±7.0	85.68 ±10.8	7.976	.000<	96.81 ±10.3	119.84 ±18.7	4.127	.009<	6.4%	6.2%

4. DISCUSSION

The present paper aimed to study the effects of 12-weeks of special exercises using rhythmic auditory to improve Spatio-temporal stride parameters, lower limb muscle activity, and 10000m racewalking time. We have observed that all measurements have been improved in post-test, favoring the experimental group.

Spatio-Temporal Stride Parameters Performance

In the present study, we found a significant difference between both experimental and control groups for the post-test in SC, and CMV favoring the experimental group, and there is no significant difference for SL. This shows that the training program with RA helps in the economy of effort by regulating the optimal relationship between SC and SL, thus improving CMV. Comparisons showed that the post-test achieved greater improvement with a large effect in STSP compared to the pre-test that achieved a small effect. In addition, there is a significant improvement in STSP parameters between both groups, favoring the experimental group as ROC= 1.62, 5.76, 7.48 % for SL, SC, and

CMV, respectively (Table 2). In the experimental group, there is a gradual increase in the cadence values of the 10000m racewalking in post-test, where the SC (step/min) for 25-samples are 180 from 1^{st} to 5^{th}, 184 from 6^{th} to 11^{th}, 188 from 12^{th} to 16^{th}, 192 from 17^{th} to 19^{th}, 196 from 20^{th} to 21^{st}, 200 for 22^{nd} to 24^{th}, and 214 for 25^{th}. Also, there is a gradual increase in velocity values that ranged from 3.47 to 4.01 m/sec. While the stride length values were appropriately balanced with the cadence values to eventually affect the gradual increase in velocity (Figure 5).

All the above indicated that the use of RA in the training produces an incremental increase in velocity by affecting the appropriate cadence and the stride length. Also, RA has indeed ubiquitous effects on motor execution and performance as movement-related sounds seem to be an integral part of the mental representation of specific movements (Kennel et al., 2014; Levitin et al., 2018). RA has been demonstrated to be effective in improving the efficacy of the motor system (Bigliassi et al., 2017), where RA is associated with stride rhythm. Thus, the racewalkers could use the RA to adapt/adjust the temporal features of their movement based on the temporal cues provided through sounds. Also, it is confirmed that training with an emphasis on the velocity aspect of the movements would be more beneficial for improving velocity by increasing stride length and/or cadence (Bartolini et al., 2011).

Lower Limb Muscle Activity Performance

It is noted that there is a significant difference between both groups in the post-test favoring the experimental group. Comparisons also demonstrated that the post-test achieved greater improvement with a large effect compared to the pre-test that achieved a small effect. Further, there is a significant improvement between both groups favoring the experimental group as ROC= 33.9% compared to 15.2% in the control group (Table 2). EMG in the experimental group was improved for all muscles favoring post-test with fixed contribution ratio in BF (L), while contribution ratio was increased in (Gmax, Gmed, BF, RF, VL, TA) (R) and VL(L) (Table 3). This is suggesting the use of RA in the training induces more focused motor unit recruitment, which leads to better muscle efficiency, thus improving the muscular activations (Sillanpää, 2007). The literature examining the effect of RA on EMG has been demonstrated to be effective in involving muscle activation (Liang et al., 2020; Thaut et al., 1992).

While EMG in (GA, SO) (R) and (Gmax, Gmed, RF, TA, GA, SO) (L) was increased with decreased contribution ratio in post-test. Where participants relied on other auxiliary muscles to a large extent in the technical, which increased the contribution ratio during the pre-test, but with the use of RA in training, the special endurance of these muscles improved, which led to a decrease in the contribution ratio of the mentioned muscles in post-test.

10000m Racewalking Time Performance

There is a significant difference between both groups in post-test favoring the experimental group, where t=3.027, P .044< .05, $\eta 2$= .483, ES= large. Moreover, there is a significant improvement between both groups favoring the experimental group as ROC= 7.03% compared to 2.94% in the control group. This amelioration resulted from the improvement of the other parameters (STSP, LLMA) using RA.

Thus, from the previous discussion, we can say that the use of RA in the training, when practiced in a regular and oriented manner, would be more beneficial for improving LLMA, STSP and RT well.

5. CONCLUSIONS

In the present paper, we aimed to study the effect of 12-weeks special exercises using RA to improve spatio-temporal stride parameters, lower limb muscle activity and 10000m record of racewalkers. The results indicated that the experience of training with RA significantly contributes to muscles activation, improved racewalkers' spatio-temporal stride parameters and racewalking times in favor of the experimental group in post-test. Thus, the paper supports the hypothesis that humans are sensitive to auditory information and encourage further studies on the role of RA in improving athletes' movement performance in sport. Therefore, the training with RA has the potential to sensitize athletes to their intrinsic sensory information, helping racewalkers to optimally improve overall performance.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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