International Journal of
EXERCISE SCIENCE

Original Research

Effects of Hypopressive Exercise on Dynamic Neuromuscular Control in Female Roller-Skaters

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ABSTRACT

International Journal of Exercise Science 17(6): 252-264, 2024. The effects of hypopressive exercise (HE) on dynamic balance have never been studied. We aimed to study the effects of a HE program on dynamic balance, posterior chain kinematics and expiratory peak flow on female competitive roller skaters over a 6-week training period. Twenty competitive female roller-skaters (13-22 years of age, SD 2.25) performed a 30-minute HE session once weekly before the regular roller-skating practice for 6 weeks. The HE program consisted of breathing and postural awareness exercises in addition to 5 basic HE poses performed three times each. Dynamic neuromuscular control was assessed with the Y-Balance Test (YBT), posterior back chain kinematics with the sit and reach test and peak expiratory flow rate with a digital spirometer. Paired *t*-test revealed significant differences between the measurement periods for all YBT leg directions and composite score ($p \le 0.01$). Significant differences were also revealed between baseline and after the intervention for the sit and reach test ($p \le 0.01$) and peak expiratory flow ($p = 0.01$). No differences in forced expiratory volume in the first second were found ($p = 0.04$). These preliminary findings suggest that a 6-week HE program could be a feasible neuromuscular option for training dynamic balance, posterior back chain kinematics and peak expiratory flow in female roller-skaters.

KEY WORDS: Balance training, skater, female athletes, injury prevention, respiratory function

INTRODUCTION

Roller skating is recognized by the International Olympic Committee as representative for the following roller-skating disciplines: Artistic, Speed, Hockey, and inline Skating. In turn, artistic roller skating is divided into different competitive disciplines such as Mandatory figures, Free skating, Solo Dance and Show and Precision skating (14). Artistic Roller Skating is a physically demanding sport that requires artistic skills, speed, agility, flexibility, and power among other aspects that can be achieved through regular training (3, 21, 26, 34).

Show is a group modality comprised of 16 to 30 skaters who perform a wide variety of synchronized elements such as intersections, intricate transitions, step sequences, complex group formations and lifts. The individual skills such as jumps with rotations in the air, footwork sequences and group lifts in show discipline increase in difficulty level with the progression of the sport. Moreover, group roller-skaters often compete in individual disciplines, increasing their hours of training and risk of injury. The most common roller-skating related injuries are acute (from falling) and overuse injuries (musculoskeletal) that occur predominantly in the lower extremity (the foot, ankle, knee, leg, hip) and in the lower back (12, 15, 35, 44, 45, 48, 50). These injuries can be a consequence of the skate, the developmental stage of the skater, the technique, weekly training hours and the elements that make up the modality such as jumps, spins, elevations, and the speed of execution (12). Despite the evolution of roller-skating and the increasing sports popularity, peer-reviewed literature on roller-skaters remains limited.

The challenging nature of roller-skating spins, jumps and equilibrium elements require adequate levels of lower extremity strength and flexibility and deep trunk neuromuscular control (7, 51). Postural stability has shown to play an essential role in sports performance whereby better athletes display more balance (18). Poor balance and core stability have been linked to lower extremity injuries (54). Neuromuscular training programs that use balance and core stability exercises have frequently demonstrated reduced injury rates and while increasing physical capabilities or performance measures (20). Many core stability exercises have been employed as means to reduce low back pain or to enhance postural control and balance in athletic populations (43, 49). Roller-skating related injuries and force stresses in landings have been found to be a product of the neuromuscular development of the skater as well as the materials used in the manufacturing of the skating boots (47).

In the last decade, Hypopressive exercise (HE) has gained attention as a postural and breathing program for deep trunk muscle training, and more recently, has been used as an exercise therapy strategy for pelvic floor dysfunctions (29) as well as a neuromuscular injury-prevention strategy by team sports professionals (4, 22, 52). HE combines postural corrective poses performed with specific breathing maneuvers with the goal of activating the deep core stabilizing musculature without placing pressure on the pelvic structures (42). The standard breathing technique is a deep, slow, latero-costal breath combined with an end-expiratory apnea associated with rib-cage expansion. This breath-holding maneuver is also known as an “abdominal vacuum” or “diaphragmatic aspiration” (11, 42). HE has been hypothesized as a means of core stability training (30, 42) due to the breathing maneuvers as well as the isometric postures performed during HE which could lead to increased abdominal wall tension (24). In support of this claim, activation of the transverse abdominis and pelvic floor muscles was described in previous studies (10, 19). A recent randomized controlled trial (RCT) reported improvements in postural control of adult females compared to the control group after 8-weeks of HE (27). Supporting data from two RCTs found improvements in low back pain mobility and pain levels in patients with non-specific low back pain compared to the control group after the 8-week HE intervention (6, 53). However, the mechanisms by which HE could influence core stability and trunk biomechanics are still poorly understood.

By using, the ribcage muscles (i.e., serratus anterior) to favor the lateral expansion of the ribcage, the thoracic diaphragm's eccentric cranial motion creates a draw-in effect on the abdominal wall (23, 53) This has been thought to influence diaphragmatic muscle strength and overall ventilatory performance (52). Vicente-Campos et al., demonstrated improved diaphragm thickness and inspiratory strength after an 8-week HE protocol compared to a control group of subjects with chronic low back pain (53). Another 8-week HE protocol was found to increase thoracic amplitude and peak expiratory flow in professional female basketball players (52). In the aforementioned study, players reduced back pain levels while improving posterior back chain flexibility (52) A similar protocol was used on female soccer players who improved posterior back chain flexibility after 6-weeks of HE (40). However, core stability gains in athletes through HE remains a question unanswered. Moreover, no published reports have assessed HE effects on postural control under dynamic stabilizing conditions.

Due to the type of postural movements and deep trunk muscle involvement from HE, we hypothesized that a HE program could be a feasible option to enhance dynamic postural control of athletes requiring elevated levels of postural stability for their sport. Additionally, the breathing maneuver involved in HE could lead to improved thoracic biomechanics and/or trunk mobility. Thus, the aim of this study was to examine if a 6-week HE program could improve dynamic postural control, posterior back chain kinematics, and maximal expiratory effort in female competitive roller-skaters. Based on previous observations in female athletes (40, 52), we hypothesized that the addition of HE would show moderate improvements in balance, flexibility, and expiratory flow in a group of competitive female roller-skaters.

METHODS

Participants

This was an uncontrolled pilot pre- and post-intervention study. A sample of 20 female athletes (14 athletes age range 13 to 17 and 6 athletes age range 18 to 22) from a roller-skating club participated in this study. A minimum of 20 subjects was determined by a priori power analysis using G*POWER (version 3.1) (13) for a power of 0.80, with an alpha level of 0.05 and an effect size of .060 based on comparable data from Teijido et al (52). Participants were recruited from Catalonia (Spain) during February 2022. All athletes competed in show discipline and 35% (n = 7) also competed in the artistic solo dance discipline. All athletes competed within the past year and trained between 2 to 3 hours daily (between 2 to 5 days a week). Demographics and sports history are outlined in table 1. Inclusion criteria included the following: a) roller-skaters competing in show modality; b) skating sport history of at least 5 years; and c) were willing to participate in the study. Exclusion criteria were not being able to participate in all HE sessions, having any contraindication to HE (such as uncontrolled high blood pressure, pulmonary or cardiac diseases) and not having previous experience with HE. All athletes were informed about the testing and data collection procedures as well as the nature of the HE program before the start of the study. Written informed consent was received from the adult participants and parental permission and child assent from them before the study. Ethical approval was granted by the Research Ethics Committee of the University of Girona (CEBRU0004-22) and was conducted in compliance of the Code of Ethics of the World Medical Association Declaration of Helsinki for experiments involving humans gathered at the 64th General Assembly, Fortaleza, Brazil, October 2013 and the relevant Spanish legislation. This study was conducted fully in accordance with the ethical principles of the International Journal of Exercise Science (28).

Table 1. Baseline anthropometric and sport history characteristics of participants.

Characteristics (*n* = 20)	Mean (SDa)
Age (years)	16.60 (2.25)
Body Height (cm)	162.70 (4.92)
Body Mass (kg)	57.84 (6.40)
Body Mass Index (kg/m2)	21.82 (2.16)
Leg Height (cm)	94.55 (4.71)
Years since started skating (years)	11.85 (2.66)
Frequency of Roller Skating Training (days per week)	3.27 (1.16)
Hours of Training (hours per week)	9.72 (4.20)
Injury History	*n* (%)
Skating related Injury History	11 (55%)
Injury due to a Fall or a Jump	5 (25%)
Lower Limb Injury	7 (35%)
Upper Limb Injury	3 (15%)
Lumbo-pelvic Injury	4 (20%)

a = Standard Deviation

Protocol

All athletes were told to refrain from vigorous exercise and to avoid smoking or consuming alcohol 24 hours before testing. All skaters were present for an initial testing session at a sports center at Girona, Spain. A single experienced skate coach performed all the testing. For all measurements and tests athletes were instructed to be barefoot. The anthropometric assessment included body height, bodyweight, and leg length. Body height was measured to the nearest 0.1 cm (about 0.04 in) with a wall height rod (Seca 222®, Semur-en-Auxois, France). Bodyweight was measured to the nearest 0.1 kg with a scale (Seca 760 Colorata®, Semur-en-Auxois, France). Leg length (distance from the ASIS to the medial malleolus of skaters landing leg in cm) was assessed with a tape measure. Primary outcome measures were dynamic balance. Secondary outcome measures were posterior back chain flexibility and peak expiratory flow rate. These field physical condition tests were previously assessed in a group of artistic skaters (46, 55).

The Y-Balance Test (YBT) (functional movement systems, Inc. Chatham, VA, USA) was used to assess dynamic balance. The YBT is a validated modification of the Star Excursion Balance that uses only the Y-Balance directions (see figure 1). The YBT has been shown to be a moderate to highly reliable tool to evaluate and valid for lower extremity injury prediction. The YBT has demonstrated good intratester reliability (31). Each Skater completed the YBT before and after the intervention program. We followed the methodology described by Plisky et al., (32). A visual and verbal demonstration of the YBT was provided to all skaters by the same investigator. Skaters were instructed to stand on one leg in the center of the foot plate while reaching with the other leg in the anterior reach (AR), posteromedial reach (PMR) and posterolateral reach (PLR) directions (see figure 1). The procedure was repeated in every direction three times. The trial was considered invalid if the moving foot touched the ground, or if the heel of the stance foot came off the ground (32). The result was normalized by leg length in cm. We used the following equation to calculate the composite score (CS) for all three average reach distances (AR, PMR and PLR) (32):

CS = [(A distance + PM distance + PL distance=/ (leg length x3)] x 100

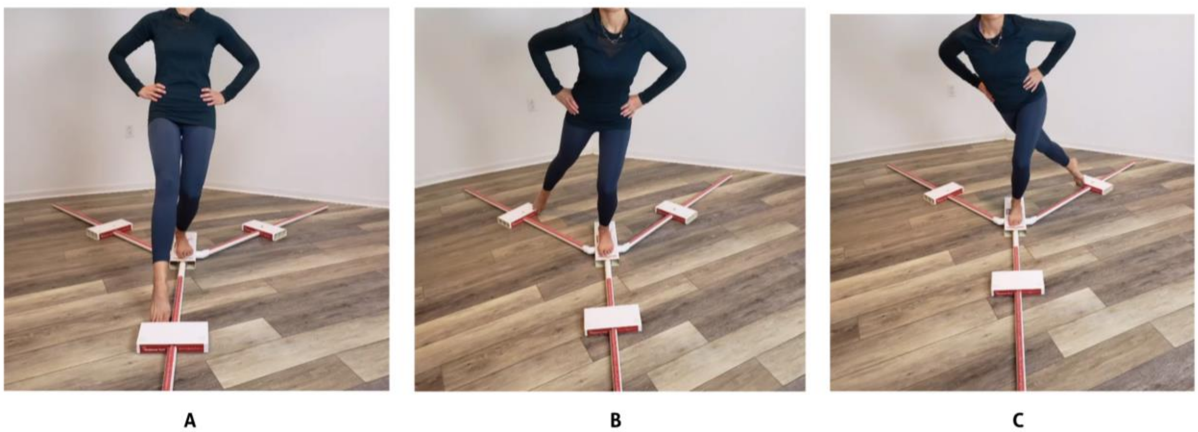

Figure 1. (A) Y balance test anterior reach; (B) Y balance test posteromedial reach; (C) Y balance test posterolateral reach

To assess kinematics of the posterior back chain, the sit and reach test (SRT) was utilized. This test was used for global assessment of hamstring and lumbar extensibility (5, 8). Skaters were instructed to sit on a mat with legs extended and soles of the feet against a 30.5 cm (about 1 ft) high SRT box. Skaters were asked to position one hand on top of the other and to bend their trunk gradually while sliding hands on top of the testing box. Each skater completed the test three times, and the best value of the three scores was noted. The American College of Sport Medicine testing guidelines for the SRT were followed (1).

Peak expiratory flow rate (PEFR) was assessed using a digital peak flow meter (model MIR Smart One® Oxi wireless). The outcomes obtained from the peak flow meter were a) Peak expiratory flow (PEF) and b) forced expiratory volume in the first second (FEV_1). PERF measures the ability to exhale and is a reliable indicator not only of ventilation but as a detector of obstructive disease or air obstruction (17). The PEFR was carried out according to the American Thoracic Society/European Respiratory Society Task Force (ATS/ERS) guidelines (15). Skaters were instructed to use a mouthpiece and to breathe quietly and normally. Then, they were indicated to inhale completely and to expire with maximum effort for at least 6 seconds. Three breathing cycles were performed, and the best of the three values were recorded.

All skaters were tested one week before and one week after the 6-week HE intervention. The 30-minute program was delivered once per week before the regular training practice in the sports center. All sessions were group based and supervised by a certified Low-Pressure Fitness trainer who had six years of experience teaching HE (E.H-R.). Daily session adherence and adverse events were recorded. No athletes had prior experience with HE. The program started with general instruction on the postural and breathing principles of HE (42). All HE exercises were performed on a mat.

During every session, the athletes were supervised and instructed for correct postural alignment and body positioning. The sessions started with breathing and posture awareness by breathing slowly through the nose and exhaling through the mouth. Lateral-costal breathing was encouraged with the cue "breath laterally as expanding your chest". Examples of motivational and postural cues were: "maintain neutral pelvis," "grow and elongate your spine towards the ceiling," "slightly incline your axis forward", and "expand your shoulder girdle". Breathing rhythm and breathing mechanics were also supervised and instructed during the HE sessions. Demonstration and observation of a rib-cage expansion associated with an abdominal draw-in was defined as an adequate abdominal vacuum form (9, 41). Demonstration, modeling and supervision of correct postural alignment and poses were performed to ensure proper understanding of coaching cues. Figure 2 shows the five basic poses executed during the program (standing, sitting, quadruped, supine and one-leg lifted bridge). Each position was repeated three times. Each repetition consisted of the maintenance of the pose while completing three breathing cycles and an abdominal vacuum maneuver at the end of the third cycle of breathing. Progression was achieved by increasing the overall duration of the apnea time. Athletes started with three to six seconds of apnea and increased each session by approximately 3 to 5 seconds. The athletes progressed to 15 to 18 seconds per exercise during the last two sessions.

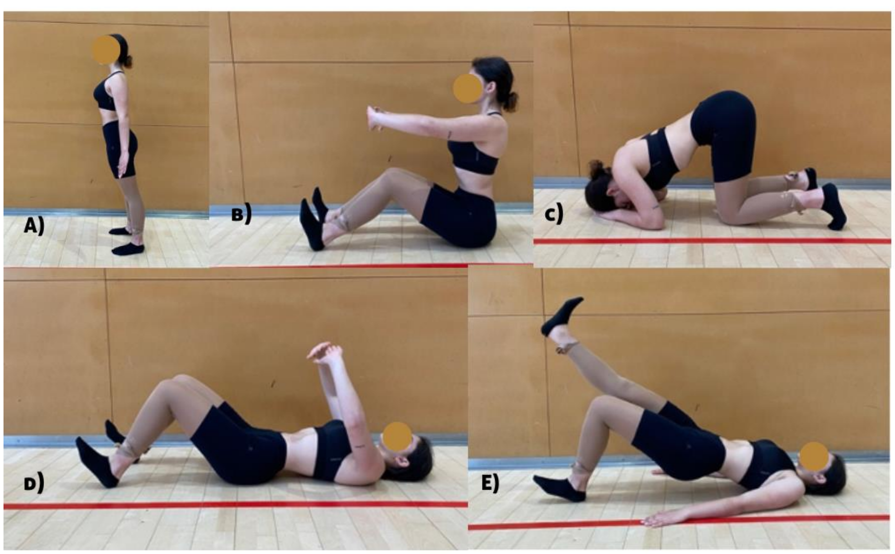

Figure 2. Example of HE poses performed in in the standing (A), sitting (B), quadruped (C), supine (D), and one-leg lifted bridge pose (E) during the study.

Statistical Analysis
A blinded specialist in statistics (not responsible for the intervention or data collection) analyzed the data. All data were recorded as means and standard deviation (SD) and 95% confidence intervals (CI) in Microsoft Excel. Then, we used the statistical package Statistical Package for the Social Sciences (SPSS), version 17.0 for the descriptive analysis and statistical analysis. To assess data normality distribution, Shapiro-Wilk test was applied. For the analysis of moments, a paired- *i* test was used for parametric variables and Wilcoxon for non-parametric variables (i.e.: Sit and reach test and posterior left leg reach) A level of statistical significance was chosen as $p \leq 0.05$ and considering a CI of 95%. Cohen's d effect sizes were calculated and interpreted according to the following scale for highly trained subjects established by Rhea (39), ≤ 0.25, trivial; 0.25-0.50, small; 0.50-1.0, moderate; > 1.0, large.

RESULTS

All participants completed all study-related tests successfully and no unexpected events or injuries occurred. No dropouts occurred. Table 1 presents the anthropometric, sports and injury history of the skaters. Table 2 presents the means and SD for all the outcome measures during the study.

After 6 weeks significant differences were found for all YBT measures. Moderate and large effect sizes were noted for all directions except for PLRL (ES = -0.13). Also, significant statistical differences were found in SRT (ES = -0.98) and PEF (ES = 0.86) after the intervention plan. FEV1 showed no statistical changes but a moderate treatment effect (ES = -0.52) Outcome measures for all variables are presented in table 2.

DISCUSSION

The main aim of this study was to examine the effects of a 6-week HE program on dynamic balance in competitive female roller-skaters. The results confirmed our initial hypothesis that a HE program can improve dynamic balance over 6-weeks of training. Overall, we found a statistically significant improvement of CS normalized to leg length and dynamic reach values for all 3 directions of the YBT.
To the best of our knowledge, this is the first study to evaluate a program of HE on dynamic control balance as well as to examine a HE program in competitive female roller skaters. A sample of healthy adult females who trained HE for 2 months demonstrated improvements on postural control assessed with a stabilometric platform (27). In the aforementioned study, the HE group showed improvements within and between the control group after the HE intervention which followed the same guidelines and exercise principles as our study (27). The observed improvements in static postural control from Moreno-Mar et al., (27) and dynamic control in our study raise the possibility of HE as an effective method of dynamic neuromuscular control training. These findings could be due to some of the postural principles from HE such as axis inclination and postural awareness. In support of this observation, HE has been found to

increase deep core muscle activation (i.e., pelvic floor, transverse, and internal oblique muscles) (9, 27) and to reduce abdominal circumference (4).

Table 2. Summary of results for all the outcome measures of the study.

Outcome Measures	Pre-test			Post-test			Post- Pre test			ES
	Mean (SD)	CI (95%)		Mean (SD)	CI (95%)		T-	CI (95%)		
		Lower	Upper		Lower	Upper		Upper	Lower	
SRT (cm)	0.44 (0.06)	0.32	0.52	0.45 (0.05)	0.32	0.55	-4.39**,	-0.02	-0.008	-0.98
PEF	322.85	281	364	353.30	315	391	-3.87**	-46.91	-13.98	-0.86
FEV^{1} (L)	2.87 (.71)	2.54	3.21	3.05 (.52)	2.81	3.30	-1.91	-.37	.01	-0.52
ARR	59.89 (6.70)	56.8	63	63.89 (6.50)	60.9	66.9	-4.74**	-5.76	-2.23	-0.98
ARL (cm)	61.30 (6.84)	58.1	64.5	64.93 (7.28)	61.5	68.3	-5.58**	-4.99	-2.27	-1.06
PMRR	103.02 (6.10)	100	106	108.64 (7.62)	105	112	-6.79**	-7.35	-3.89	-1.51
PMRL	102.51 (6.87)	99.3	106	110.10 (8.08)	106	114	-	-8.91	-6.26	-2.67
PLRR	97.42 (7.12)	94.1	101	100.06	90.2	110	-.60*, w	-11.81	- .60	-0.75
PLRL	97.82 (8.29)	93.9	102	107.25 (9.64)	103	112	-8.26**	-11.81	-7.04	-0.13
CSR (%)	91.90 (5.30)	--	--	97.82 (6.66)	--	--	-8.42**	-7.39	-4.44	-1.88
CSL (%)	92.33 (6.19)	--	--	99.62 (6.88)	--	--	-	-8.45	-6.12	-2.93

SRT: sit and reach test (cm/leg length); PEF: peak expiratory flow; FEV$_1$: forced expiratory volume in the first second; ARR: anterior reach right leg; ARL: anterior reach left leg; PMRR: posteromedial reach right leg; PMRL: posteromedial reach left leg; PLRR: posterolateral reach right leg; PLRL: posterolateral reach left leg; CSR: composite score right leg; CSL: composite score left leg; SD: Standard deviation; CI: confidence Intervals; T: value; t-test; **: p ≤0.01; *: p≤0.05. w: Wilcoxon test; Es: Effect Size

Previously, Staler et al., (46) examined YBT performance in elite figure skaters (ice dancers, single and pair skaters) in males and females. The average CS of our sample was 92%, similar to the CS values of female single ice skaters (92-94%) described in Slater et al. (46) but slightly lower than figure roller skaters (95-96%) assessed by Rebelo et al., (37). Female ice skaters from Slater et al. (46), demonstrated approximately 3 cm of decreased PLR on the landing leg. Interestingly, Rebelo et al., (37) found that freestyle skaters performed better on the PLRR leg than skaters from figure discipline as well. These results may be associated with limb asymmetry from the specific jump routine of the roller-skaters who perform take off with the same leg, leading to non-uniform limb performance. Elite skaters have significant asymmetries between lower limbs which may place them at greater risk for injuries (38).

Our findings showed increased posterior back chain flexibility assessed with the SRT. Similar results on improved back chain kinematics after a HE program were found in previous studies on female basketball (52) and soccer players (40). The study by Teijido et al. (52) found significantly improved values of the SRT and the finger to floor test after 4 and 8-weeks of a HE intervention on a group of professional basketball players. Similarly, a sample of young female soccer players also displayed improvements in the finger to floor test after a 6-week HE intervention (40). However, these studies were of an uncontrolled nature. A recent RCT in patients with chronic low back pain found improvements in lumbar flexibility after eight sessions of HE (6). Collectively, these findings suggest that a 4 to 8-week program of HE could improve flexibility of the posterior back chain. The mechanisms by which HE could affect flexibility remain unclear. Increased ankle and hip angles from the exercise poses or the impact of the breathing maneuver on diaphragm neuromuscular conditions are some plausible hypotheses.

The ventilatory parameters assessed in our study showed PEF improved values and non-significant changes in FEV_1. Our results are contradictory from the results obtained in female basketball players who displayed improvements in both PEF and FEV_1 assessed through spirometry following HE (52). In this sample of basketball players, forced vital capacity values did not increase while an improved costal expansion was noted. The breathing exercises of HE could have impacted some mechanical aspects of breathing. Vicente-Campos et al. (53) found increased diaphragm thickness and maximal inspiratory pressure after an 8-week HE program in patients with low back pain. The differences in physical and ventilatory conditioning between clinical and athletic populations may explain, at least in part, the variability of the discussed results. The breathing practice of HE may not be intense enough to elicit overall improvement in pulmonary function in athletes except for variables related with maximal expiratory efforts such as PEF. In fact, key cardiopulmonary and ventilatory parameters are higher in elite athletes compared to ordinary peers (25). As part of the trunk musculature, it has been hypothesized that the diaphragm and deep abdominal muscles aid in balance and core stability. In fact, lower limb muscle strength was found to be correlated with respiratory muscle strength in a sample of young elite athletes (2). Expiratory flow limitation in non-asthmatic and asthmatic athletes is a common finding during exercise whereby higher ventilatory requirements are no longer able to meet the higher metabolic demands (36, 51). Of note, increased rib-cage motion and deep trunk muscle activation described in previous studies from HE (19, 27, 52) may enable athletes to generate a more efficient expiratory pattern during maximal physical efforts.

A strength of our paper is the record of injury history in a sample of competitive female roller-skaters in the show discipline. However, this study has a few limitations. First, the non-controlled design of the trial. Secondly, the specific nature of our athletic population doesn't allow for generalizability of the results to other groups. Our sample consisted of adolescent and young adult skaters. We did not assess maturation status of the skaters which could limit the interpretation of our results. Further studies should consider biological maturation, separate age groups as well as randomized controlled designs comparing HE to traditional exercise protocols in female and male skaters. Lastly, another limitation was the reduced number of practice sessions that could have impacted results. Long-term follow-up studies of HE are lacking. Because this is the first study to assess the effects of HE on performance measures in young roller skaters, these preliminary findings could stimulate further research regarding HE and help to recognize the potential applications of HE for athletes' physical performance or injury prevention.

ACKNOWLEDGMENTS

We would like to acknowledge and thank the participants of this study.

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