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ENERGY DRINK CONSUMPTION AMONG PHYSICALLY ACTIVE PERSONS IN LEBANON: A MULTICENTER CROSS-SECTIONAL STUDY

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Abstract **Introduction:** Energy drinks (EDs) are caffeinated drinks marketed as energy and performance boosters and commonly used by athletes worldwide. They are widely used among youth and university students, with limited research about their

consumption among physically active persons. **Objectives:** This study aims to assess ED consumption among physically active persons in Lebanon, the association between ED use and the participants' general characteristics, and to explore the predictors of ED use among them. **Methods:** An observational cross-sectional study was conducted over three months, targeting 384 physically active persons from 8 gyms across Lebanon. **Results:** The prevalence of ED consumption was 49.2%, namely to boost energy (68.2%) and stimulate awakeness (19.3%). Around 20% used EDs during workouts, and 15.8% used them before it. Females had 59% lower odds of ED consumption than males (OR 0.41, 95% CI 0.19–0.89), while older participants had 4.74 times higher odds of ED use (OR 4.74, 95% CI 1.16–19.3). Waterpipe smokers and alcohol consumption had 3.68 and 2.28 times higher odds of ED use than non-users. Among other sports, those doing weightlifting had significantly higher odds of ED consumption than others (OR 2.61, 95% CI 1.30–5.25). **Conclusion:** The predictors of ED consumption should be considered for better-informed decisions and effective awareness campaigns.

Key words: energy drinks, consumption, physically active persons, physical activity, predictors

Introduction

Caffeinated drinks are the most consumed and socially accepted stimulants, with approximately 90 percent of all adults worldwide consuming coffee and tea regularly (Knapik et al., 2022). Among others, energy drinks (EDs) are caffeinated drinks marketed as an energy and performance boosters and commonly used by athletes worldwide. They are soft drinks with a high sugar content, caffeine, and other stimulants such as taurine, l-carnitine, and herbal extracts (Peacock et al., 2013). EDs were initially marketed in Europe and Asia in the 1960s but remained unpopular until "Red Bull" was merchandized in Austria in 1987 and was afterward advertised worldwide (Grósz & Szatmári, 2008). EDs differ from sports drinks because the latter drinks do not contain caffeine or any other stimulant and are not intended to have any stimulant or energizing effect (Pound et al., 2017).

In contrast to the claimed advantageous effects of EDs, consuming these drinks may usually be associated with several unintended side effects, which according to the World Health Organization, are attributed to high caffeine levels (Siddique, 2014). Among others, insomnia, nervousness, headache, tachycardia, and seizures are the most reported side effects (Alamzeb Jadoon et al., 2022; Yusupova & Firdavs, 2022). An experimental study recently published reported a significant increase in hepatic and renal biochemical parameters following 3 months of consumption of EDs in rats (Mukhiddinovna, 2022). Noticeable changes were also observed among humans in the levels of low-density lipoproteins (LDL), triacylglycerols (TAG), and triiodothyronine (T3) up to 21 days after ED consumption (Akramovna, 2022). Furthermore, research found a possible contribution of ED consumption to the development of cardiovascular disorders, and changes in the gastrointestinal tract, leading to significant metabolic effects (Yusupova & Firdavs, 2022). Some consumers combine EDs with alcohol, sometimes leading to death (Nurmurodovna, 2022). A recent study showed a higher willingness to drive after consumption of such a combination than drinking alcohol solely, putting consumers and other people at a high risk of accidents (Pérez-Mañá et al., 2022).

EDs were reported to be used by teenagers to mask other tastes such as alcohol, counteract the behavioral effects of alcohol and provide more energy for prolonged activity during exams and stressful periods (Graczyk et al., 2022). Among athletes, they are primarily used to improve focus, alertness, and performance (Tambalis, 2022). In 2012 and to manage ED use and its corresponding outcomes, the Lebanese ministries of Economy and Health issued a policy targeting energy drinks' importers and producers to lower the caffeine level from 65 to 35 grams (*mTV Lebanon*, 2013). Nevertheless, no further steps were taken, with a lack of law application since, for example,

a Red Bull still contains 80 mg of caffeine. Moreover, advertising campaigns promoting ED use are allowed without highlighting the possible adverse events of such consumption. In Lebanon, ED consumption is common, mainly among youth and university students (63.6%) (Itany et al., 2014), with no study assessing their use among physically active persons. Moreover, the pandemic has significantly impacted sports practices and events worldwide. While the specific guidelines and regulations can vary depending on the country and region, in Lebanon, restrictions on group sizes, social distancing measures, and hygiene practices were imposed (Hatem & Goossens, 2022), in addition to regular cleaning and disinfection of equipment and facilities and any commonly used areas such as locker rooms or restrooms (Piotrowski & Piotrowska, 2021). This study aims to assess (i) ED consumption among physically active persons in Lebanon, (ii) the association between ED use and the general characteristics of the participants, and (ii) to explore the predictors of ED use among them.

Methods

Study design

An observational cross-sectional study was carried out over three months (August–October 2022), targeting physically active persons from 8 gyms in Lebanon.

Study sample and sample size

Participants were recruited with no selection criteria based on sex, nationality, age, or ethnicity. Two gyms were located in Beirut, three in Mount Lebanon, and one in South, North, and Bekaa, respectively. Participants who refused to answer the survey and those practicing sports for less than three months were excluded. The sample size was determined using the Epi Info 7 software. The calculation assumed that the probability of consumption of EDs was 45% based on findings from a recent study published in Lebanon (Ghozayel et al., 2020). Considering a 95% confidence interval and a 5% acceptable margin of error, 381 participants were required. GPower 3.1. was used to perform a power analysis since 384 participants were included and a power of 87.5% was achieved.

Data collection

Three pharmacy students approached the participants during weekdays from 10 am to 4 pm and explained the study objectives orally. They invited them to participate by filling out a survey on a tablet. The first page of the survey mentioned above included a written version of the objectives with an estimated 12 minutes to answer.

Study tool

A questionnaire was developed and used for data collection. It was available in Arabic (the official language in Lebanon). The survey was initially piloted on 20 participants, and questions that needed more clarity were adjusted or deleted. The first part included questions about the general characteristics of the participants including sex, age (<18, 18–30, and >30), the level of education (elementary school, high school, and university or more), the governorate of residence, and the household arrangement (with family or alone). This part also collected the lifestyle habits and sport practices of the sample such as smoking (cigarettes and waterpipe), alcohol consumption, type of sports (running, weightlifting, swimming, biking, and football). The frequency of practicing sports was also

reported in addition to the place of workout (gym, outdoors, and home) and if they had a workout partner. The second part of the survey comprised questions related to ED consumption. Participants were asked if they agree to 15 statements related to EDs including their use and the intended reasons, place and context of consumption, and the different side effects of ED use. They reported the frequency of ED consumption, if they encountered any side effects, whether or not they mix EDs with alcohol, and their perceived satisfaction and dependence on EDs.

Statistical analysis

Statistical analyses were performed using Statistical Package for Social Sciences (SPSS Inc, Chicago, Illinois) Version 28. Categorical variables are presented through frequencies and percentages. These variables included the general characteristics of the participants, their lifestyle habits, sport practices and questions related to ED consumption. In contrast, continuous variables such as the age, BMI, and sport frequency per week are presented in means and standard deviations**.** Considering the values of skewness (0.017) and kurtosis (0.271), data are normally distributed and converged toward their expected values (Hatem et al., 2022). Bivariate analyses were performed to test the association between ED use among physically active persons, and their general characteristics. Chi-square/ Fisher exact tests were used to compare percentages between the associated categorical variables. The unpaired student t-test/ Mann-Whitney test was used for the comparison of data between two different groups. A multivariate analysis using a logistic regression model was performed to assess the predictors of ED consumption. These analyses produced Odd Ratios with a 95% Confidence Interval (CI). Independent variables were only selected if they had p-values <0.20 in bivariate analyses. A p-value <0.05 was considered statistically significant.

Ethical considerations

The study protocol, survey, and consent form were reviewed and approved by the institutional review board of the faculty of pharmacy of the Lebanese University. Data were completely anonymous and non-identifiable. Written informed consent was obtained from each participant by asking them to sign before filling out the survey. They were acknowledged that they could withdraw their participation at any point during the interview and that findings would only be used for research purposes.

Results

General characteristics of the participants

Overall, 437 potential participants were approached, and 384 agreed to participate in the study (87.9%). The general characteristics of the sample are presented in Table 1. The sample included more males (N = 291, 75.8%) than females (N = 93, 24.2%). The mean age was 26.2 (1.6), with the majority (69.3%) between 18 and 30 years. Most students (93.3%) were less than 30 years of age and had a university degree or more (74.0%). As regards the governorate of residence, participants were distributed in five governorates, with Mount Lebanon (48.2%), North (20.8%), and Beirut (16.7%) accounting for the highest proportions. Three-thirds lived with their family. Around 48% of the participants were cigarette smokers, 29.9% were waterpipe smokers, and 48.2% were passive smokers. Weightlifting (68.8%), running (46.4%), and swimming (29.0%) were the most common type of sports, while muscle gain (62.2%) and weight loss (37.0%) were the main reasons for practicing sports. More than half of the sample (56.8%) exercised for more than 4 days, 75.3% regularly went to the gym, and 51% had a workout partner.

Table 1. Distribution of the general characteristics of physically active persons in the study sample

		Total (N = 384)
		Frequency (%)
Sex	Male	291 (75.8%)
	Female	93 (24.2%)
Age (years)	**Mean ±SD**	26.2 ±1.6
	<18	52 (13.5%)
	18–30	266 (69.3%)
	>30	66 (17.2%)
BMI	**Mean ±SD**	24.6 ±3.1
Level of education	Elementary school	23 (6.0%)
	High school	77 (20.1%)
	University or more	284 (74.0%)
Governorate of residence	Beirut	64 (16.7%)
	Mount Lebanon	185 (48.2%)
	North	80 (20.8%)
	South	36 (9.4%)
	Bekaa	19 (4.9%)
Household arrangement	With family	290 (75.5%)
	Alone	94 (24.5%)
Cigarette smoking (N = 254)	Smoker	121 (47.6%)
	Non-smoker	133 (52.4%)
Waterpipe smoking (N = 254)	Smoker	76 (29.9%)
	Non-smoker	178 (70.1%)
Passive smoking	Yes	185 (48.2%)
	No	199 (51.8%)
Alcohol consumption	Yes	84 (21.9%)
	No	300 (78.1%)
Type of sports practiced	Running	178 (46.4%)
	Weightlifting	264 (68.8%)
	Swimming	111 (29.0%)
	Biking	60 (15.7%)
	Football/ Basketball	46 (12.0%)
Reasons for practicing sports	Muscle gain	239 (62.2%)
	Weight loss	142 (37.0%)
	Hobby	99 (25.8%)
	Health reasons	49 (12.8%)
Sports frequency per week	**Mean ±SD**	4.4 ±1.6
	≤2 days	40 (10.4%)
	3–4 days	126 (32.8%)
	>4 days	218 (56.8%)
Workout location	Gym	289 (75.3%)
	Outdoors	143 (37.2%)
	Home	34 (8.9%)
Workout partner	Yes	196 (51.0%)
	No	188 (49.0%)

Results are given in terms of frequency (percentage) or Mean ± Standard Deviation.

Energy drinks consumption among physically active persons

Table 2 presents the prevalence, characteristics, and perceptions of ED use among physically active persons. The prevalence of ED consumption in the sample was 49.2%. The reasons for using them were mainly to boost energy (68.2%) and stimulate awakeness (19.3%). Around 20% used EDs during workouts, and 15.8% used them before it. Family (19.7%) and friends (21.7%) gatherings were the main occasions for using EDs, with higher consumption in public places (48.4%) than at home (26.3%). Only 9% declared that they feared being addicted to EDs, and 30.9% said that they used safer alternatives for energy stimulation. Almost 20% of the participants used

EDs daily, and 17.4% used them weekly. More than half of physically active persons (56.3%) encountered side effects from EDs, with tachycardia (41.3%), headaches (18.5%), and agitation (18.0%) as the most common ones. Seventy percent of the participants reported never mixing EDs with alcohol, and only 12.3% always did it. Only 13.1% of them said they depended on EDs, and 47.5% felt satisfied after consuming them.

Table 2. Energy drink consumption among physically active persons in Lebanon

		Total (N = 384)
Do you agree with the following?		**Frequency** (%)
I regularly use energy drinks		189 (49.2%)
I use energy drinks to stimulate awakeness		74 (19.3%)
I use energy drinks to boost my energy		262 (68.2%)
I use energy drinks to boost my mental activity		15 (3.9%)
I use energy drinks when doing sports (N = 244)		49 (20.1%)
I use energy drinks before workouts (N = 244)		38 (15.8%)
I use energy drinks during exams/stressful periods (N = 242)		22 (9.1%)
I use energy drinks to be awake at night (N = 244)		90 (36.9%)
I only use energy drinks during family gatherings (N = 244)		48 (19.7%)
I only use energy drinks with friends (N = 244)		53 (21.7%)
I only use energy drinks at home (N = 244)		64 (26.3%)
I only use energy drinks in public places (N = 244)		118 (48.4%)
I fear being addicted to energy drinks		23 (9.0%)
I use safer alternatives for energy stimulation		79 (30.9%)
Energy drinks have side effects	Yes	230 (59.9%)
	No	39 (10.2%)
	I don't know	115 (29.9%)
Frequency of energy drinks consumption (N = 190)	Daily	39 (20.5%)
	Weekly	33 (17.4%)
	Monthly	11 (5.8%)
	Occasionally	107 (56.3%)
Side effects from energy drinks	Yes	129 (52.9%)
(N=244)	No	115 (47.1%)
Please cite them	Tachycardia	85 (41.3%)
	Headache	38 (18.5%)
	Agitation	37 (18.0%)
	Frequent urination	28 (13.7%)
	Nausea	24 (11.7%)
	Gastrointestinal	12 (5.9%)
Mixing energy drinks with alcohol (N = 243)	Never	170 (70.0%)
	Rarely	32 (13.2%)
	Usually	11 (4.5%)
	Always	30 (12.3%)
Energy drinks can (N = 244)	Stimulate awakeness	74 (30.3%)
	Boost energy	107 (43.9%)
	Improve confidence	13 (5.3%)
	Improve mental state	26 (10.7%)
Satisfaction with energy drinks (N = 244)	Yes	116 (47.5%)
	No	128 (52.5%)
Energy drinks dependence (N = 245)	Yes	32 (13.1%)
	No	213 (86.9%)

Results are given in terms of frequency (percentage)

Association between energy drink consumption and the general characteristics of the participants

Table 3 shows the association between ED use and the participants' general characteristics. Males reported significantly higher ED use than females (55% and 31.2%, respectively, $p < 0.001$). Although no differences were noted when taking age as a covariate, it was noted that physically active persons younger than 18 years used fewer EDs than their older peers (34.6%, $p = 0.074$). Smoking, in general, was associated with ED consumption where compared to non-smokers, cigarette (62.8% vs. 49.6%, $p = 0.035$), waterpipe (73.7% vs. 48.3%, $p < 0.001$) and passive (62.7% vs. 36.7%, $p < 0.001$) smoking was associated with the consumption of EDs. Furthermore, 69% of alcohol drinkers used EDs compared to 43.7% of non-drinkers ($p < 0.001$). Regarding the association with the type of sports practice, those doing weightlifting had significantly higher ED consumption than those who did not (53.8% vs. 39.2%, $p = 0.008$). Moreover, 56.6% of physically active persons having a workout partner used EDs compared to 41.5% of those practicing alone ($p = 0.003$).

Table 3. Association between energy drink consumption and the general characteristics of the participants

Energy drinks consumption among athletes		**Yes** (N = 185)	**No** (N = 195)	
		Frequency (%)	**Frequency** (%)	**p-value**
Sex	Male	160 (55.0%)	131 (45.0%)	**<0.001**
	Female	29 (31.2%)	64 (68.8%)	
Age (years)	<18	18 (34.6%)	34 (65.4%)	
	18–30	136 (51.1%)	130 (48.9%)	0.074
	>30	35 (53.0%)	31 (47.0%)	
Level of education	Elementary school	12 (52.2%)	11 (47.8%)	
	High school	31 (40.3%)	46 (59.7%)	0.212
	University or more	146 (51.4%)	138 (48.6%)	
Governorate of residence	Beirut	30 (46.9%)	34 (53.1%)	0.432
	Mount Lebanon	86 (46.5%)	99 (53.5%)	
	North	41 (51.2%)	39 (48.8%)	
	South	19 (52.8%)	17 (47.2%)	
	Bekaa	13 (68.4%)	6 (31.6%)	
Household arrangement	With family	149 (51.4%)	141 (48.6%)	0.137
	Alone	40 (42.6%)	54 (57.4%)	
Cigarette smoking (N = 254)	Smoker	76 (62.8%)	45 (37.2%)	**0.035**
	Non-smoker	66 (49.6%)	67 (50.4%)	
Waterpipe smoking (N = 254)	Smoker	56 (73.7%)	20 (26.3%)	**<0.001**
	Non-smoker	86 (48.3%)	56 (73.7%)	
Passive smoking	Yes	116 (62.7%)	69 (37.3%)	**<0.001**
	No	73 (36.7%)	126 (63.3%)	
Alcohol consumption	Yes	58 (69.0%)	26 (31.0%)	**<0.001**
	No	131 (43.7%)	169 (56.3%)	
Weightlifting	Yes	142 (53.8%)	122 (46.2%)	**0.008**
	No	47 (39.2%)	73 (60.8%)	
Biking	Yes	23 (38.3%)	37 (61.7%)	0.063
	No	166 (51.4%)	157 (48.6%)	
Sports frequency per week	≤2 days	20 (50.0%)	20 (50.0%)	
	3–4 days	53 (42.1%)	73 (57.9%)	0.137
	>4 days	116 (53.2%)	102 (46.8%)	
Workout partner	Yes	111 (56.6%)	85 (43.4%)	**0.003**
	No	78 (41.5%)	110 (58.5%)	

Results are given in terms of frequency (percentage). P-values <0.05 are considered statistically significant.

Predictors of energy drink consumption among physically active persons

The predictors of ED use among physically active persons are presented in Table 4. After adjusting for covariates, females had 59% lower odds of ED consumption than males (OR 0.41, 95% CI 0.19-0.89). The odds of ED use were 4.74 times higher among those older than 30 years compared to physically active persons younger than 18 (OR 4.74, 95% CI 1.16–19.3). Waterpipe smokers had 3.68 times higher odds of ED use than non-smokers (OR 3.68, 95% CI 1.85–7.33). Moreover, passive smokers had 2.84–fold higher odds of ED consumption than other participants (OR 2.84, 95% CI 1.57–5.15). Alcohol consumers had 2.28 times higher odds of ED use than non-consumers (OR 2.28, 95% CI 1.14–4.58). Among others, those doing weightlifting had significantly higher odds of ED consumption than others (OR 2.61, 95% CI 1.30–5.25).

Table 4. Predictors of energy drink consumption among physically active persons

	Crude model	Adjusted model	p-value
	OR [95% CI]	OR [95% CI]	
Female sex (male as reference)	0.37 [0.23–0.61]	0.41 [0.19–0.89]	**0.024**
Age (<18 as a reference)			
18–30	1.98 [1.06–3.67]	3.06 [0.91–10.3]	0.072
>30	2.13 [1.01–4.51]	4.74 [1.16–19.3]	**0.030**
Living alone (With family as a reference)	0.70 [0.44–1.12]	0.54 [0.26–1.14]	0.106
Cigarette smoking (No as a reference)	1.71 [1.04–2.83]	0.67 [0.33–1.33]	0.248
Waterpipe smoking (No as a reference)	2.99 [1.66–5.40]	3.68 [1.85–7.33]	**<0.001**
Passive smoking (No as a reference)	2.90 [1.92–4.39]	2.84 [1.57–5.15]	**<0.001**
Alcohol consumption (No as a reference)	2.88 [1.72–4.82]	2.28 [1.14–4.58]	**0.020**
Weightlifting (No as a reference)	1.81 [1.17–2.81]	2.61 [1.30–5.25]	**0.007**
Biking (No as a reference)	0.59 [0.33–1.03]		
Sports frequency (≤2 days as a reference)			
3–4 days	0.73 [0.36–1.48]		
>4 days	1.14 [0.58–2.23]		
Workout partner (No as a reference)	1.84 [1.23–2.76]	1.58 [0.88–2.82]	0.122

Question: Do you consume energy drinks? The baseline answer is "No". OR: Odds ratio; CI: Confidence Interval
Omnibus test (p < 0.001), Nagelkerke r square (0.287), Hosmer & Lemeshow (p = 0.016)

Discussion

The present study aimed to assess ED consumption among physically active persons and the predictors of ED use. A high prevalence of ED consumption was reported among participants, namely for energy boosting and stimulating awakeness. More than half of physically active persons encountered side effects from ED consumption, particularly tachycardia and headaches. Around 30% of participants reported mixing EDs with alcohol, and 13.1% reported dependency.

Around half of the participants reported using EDs. A recent study showed a correlation between ED use and the perception of athletic identification and sports participation (Pfender et al., 2023). Moreover, a systematic review published in 2022 found that ED consumption increased the probability of risky behaviors, anxiety, depression, and impulsivity in addition to a progressive increase in consumption within 5 years (Silva-Maldonado et al., 2022). Previous research conducted among young athletes in the United States showed a higher prevalence (80.1%) than in this study (Hoyte et al., 2013). Since most participants in this study were adults, this might be due to the

lower consumption of EDs among this group compared to younger ages (32% vs. 68%) (Erdmann et al., 2021). In Lebanon, studies reported a slightly lower prevalence of ED use (45%) among university students (Ghozayel et al., 2020), but much higher among adolescents and youth (Itany et al., 2014). Many physically active persons in this study used EDs to enhance their physical performance, making them prone to side effects such as insomnia, heart palpitation, hypertension, and anxiety (Dwaidy et al., 2018). Tachycardia was the most reported side effect in this study, which was also reported among young adults using EDs (Costa et al., 2023) and among athletes (Guerra et al., 2023). The study sample was predominantly men. Research showed gender differences in exercise habits and motives, where men tended to exercise more for fitness and shape toning while women focused on weight loss and health quality (Craft et al., 2014). As regards ED use, men reported a significantly higher consumption than women, in agreement with previous reports (Fagaras et al., 2023; Llorent-Bedmar et al., 2023).

Most participants used EDs to boost their energy, with 36% using them before or during the workout. This misuse can lead to substantial health outcomes, such as pre-workout-induced ischemia (Guerra et al., 2023), and an increase in blood sugar levels (Ragsdale et al., 2010). Smoking (cigarettes, waterpipe, or passive) was associated with higher ED consumption. This finding was also reported in previous studies (Larson et al., 2014; Pavlovic et al., 2023), where physically active persons and smokers had significantly increased use of EDs compared to others. Tobacco consumption in ED advertising (Bleakley et al., 2022), could explain this finding and call for better supervision, due to the harmful effect of substance abuse since cigarettes are cheap in Lebanon. Participants practicing weightlifting reported greater use of EDs. Weightlifting training was reported to be ameliorated with the consumption of caffeinated drinks (Menezes et al., 2022). They are mainly used to boost energy and hydration and were found to improve both aerobic and anaerobic exercise performance (Tambalis, 2022) but should be considered with caution. Working out with a partner significantly increased ED consumption, possibly related to using them as socialization tools and the self-perception of better engagement in sports (Attila & Çakir, 2011). Among the reported predictors, alcohol consumption was found to significantly induce ED use among the participants. This finding was also shown in previous research, where a high proportion of ED users tended to mix them with alcohol (Attila & Çakir, 2011; Llorent-Bedmar et al., 2023; Pavlovic et al., 2023).

This study has limitations. Selection bias may have been induced since the data collectors conveniently selected the participants in the gyms. Recall bias can affect the findings since a self-reported survey was used for data collection. However, pharmacists were uniformly trained and used the same data collection form, and a different researcher performed data coding and analysis. Despite the multi-center aspect of the study, participants were only recruited from selected gyms; therefore, results cannot be extrapolated to other physically active persons or to those practicing outside these settings. Nonetheless, the present study is among the few studies tackling the consumption of ED among physically active persons and the predictors of this consumption. Findings can allow better-informed decisions and tailored campaigns targeting this specific group.

Conclusion

A high prevalence of energy drink consumption was found among physically active persons in Lebanon. Despite the reported side effects, EDs were commonly used as energy boosters and awakeners. After adjusting for covariates, ED use was significantly higher among females, waterpipe and passive smokers, alcohol drinkers, and those practicing weightlifting. For better informed-decision and effective awareness campaigns, these predictors should be considered.

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PRESS UP EXERCISES AS AN ALTERNATIVE TO CONVENTIONAL THERAPY OF RADICULAR SYMPTOMS IN PATIENTS WITH LOW BACK PAIN

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Abstract The study examines whether clinical and objective improvement can be achieved in patients with LBP (low back pain) with radicular symptoms using a 6-week exercise program based on press up exercises created from ADL (activities of daily living) movement patterns. This original study involved 10 men with acute L5 / S1 disc hernia. Before starting the exercise program, patients determined the intensity of pain VAS (Visual Analogue Scale), the intensity of paraesthesias (NSIP: numerical

scale of paraesthesia intensity) and the location of paraesthesias. Magnetic resonance imaging (MRI) was used to objectify the extent of the disc hernia, spinal cord compression, and pressure acting on the dural sac. Patients completed -week exercise program consisting only of press up ADL movement patterns in a closed kinematic chain. At the end of the exercise program, patients determined the outcome values of clinical symptoms and underwent control MRI within 2 weeks at the latest. At the end of the study all patients showed a statistically significant reduction in pain intensity ($p = 0.005$), paraesthesia ($p = 0.006$). The pressure on the dural sac was reduced in all patients. One of the patients had a partial reduction of intervertebral disc hernia by 35.7%. None of the patients had a change in spinal root compression. Conventional therapy should focus on influencing clinical symptoms that appear to correlate with dural sac compression. We dare to argue that reduction of hernia disc is not a sign of primary recovery in LBP patients with acute phase radicular symptoms.

Key words: ADL (activities of daily living), spinal disc herniation, dural bag, motor learning, paresthesia

Introduction

Inadequate primary prevention of postural health in childhood, continuing in adulthood, results in the formation of structural disorders of the musculoskeletal system, the manifestation of which is pain. The lack of physical activity in the movement regime is one of the factors that supports the mentioned upward trend of musculoskeletal diseases.

Currently, low back pain (LBP) is one of the most frequently diagnosed diseases of the musculoskeletal system. Surveys show that about 80% of the population have personal experience with LBP with radicular symptoms, while 40% of them suffer from backache once a year (Adams, 2000 Hayden et al., 2010; Stefanakis et.al., 2012; Huijnen et al., 2020; Maniadakis & Gray, 2000). Approximately 2–5 % of the population suffer from radicular symptomatology, which is caused by intervertebral disc herniation according to most authors (Adams et al., 2010; Turk et al., 2019; Cavalcanti et al., 2020; Ozcamdalli et al., 2020). Another theory of etiopathogenesis of radicular symptomatology works on the principle of pathological changes in the blood supply caused not only by a herniated disc but also changes in the posterior longitudinal ligament (Komori et al., 1996; Adams, 2005; Adams et al., 2010; Stefanakis et al., 2012). Therefore, radicular symptoms should result from uneven loading of intervertebral discs. Summation of asymmetric loading, i.e., creep phenomenon, accelerates degeneration of a disc, which succumbs to exerted forces and thus herniates at some point. The resulting hernia impacts surrounding tissues, in particular the tissues placed in the intraforaminal space. The pressure on intraforaminal structures and the dural bag, which protects them, increases. There is not only mechanical oppression of neural structures by the herniated disc, which can lead to an inflammatory response and chemical pain, but also pressure accumulation of interacting tissues in the dural bag. The result is dural bag compression and increased tension of the posterior longitudinal ligament. One of the most frequent causes of LBP with radicular symptoms is disc herniation diagnosed in the L4/L5 or L5/S1 segments (Adams, 2005; Adams & Roughley 2006; Adams et al., 2010; Stefanakis et al., 2012).

Although this is a quite common diagnosis, no optimal therapeutic procedure guaranteeing effective treatment has been found. Since disc herniation occurs the most frequently on the basis of repeated pathological loading of the spine, it is necessary to focus not only on structural changes, which can be monitored during magnetic resonance imaging, but also on clinical symptomatology associated with relevant daily living activities of a patient (Choi et al., 2010; Nemček, 2016; Cavalcanti et al., 2020; Ozcamdalli et al., 2020).

Today, occupations which are potentially risky for occurrence of radicular symptomatology prevail. These are activities with predominantly flectional loading of the spine, e.g., desk jobs (IT branch, drivers, office jobs), but

also manual work, such as a locksmith or a bricklayer, where intradiscal pressure increases. All "risky" occupations have a linking factor in the form of a flexed position of the spine, which causes simple local ligament pain at the beginning. If these people prefer activities or spine positions increasing intradiscal pressure in their leisure time, probability of occurrence of pathological changes in the intervertebral disc significantly rises (Kerr et al., 2001; Ganesan et al., 2017; Samiei et al., 2019; Adams et al., 2000). Summation of asymmetric loading of a disc results in its pathological degeneration and pressure exerted on the surrounding neural structures starts to increase. Clinical response changes and local pain is replaced by radicular symptoms, which are not present only in the form local backache. This is a vicious circle when people tend to search for antalgic positions in an effort to relieve pain. These positions can temporarily reduce local backache, but they often do not impact or they even worsen peripheral symptomatology caused by recurrent pressure increase in the dural bag (Adams, 2005; Adams & Roughley, 2006; Stefanakis et al., 2012).

Therefore, we consider it useful to apply motor patterns based on ADL of the general population to conventional therapy of patients with LBP. The managed therapy will not only reduce clinical symptoms during a workout with a physiotherapist but after primary fixation of motor learning new more effective motor patterns for ADL will be automated. The therapy consisting of modified motor patterns for ADL can be used also as a self-therapy. Practising and mastering motor skills in the closed kinematic chain (CKC) is an essential factor of correct performance of activities in the open kinematic chain (OKC) according to (Dvořák 2005a, 2005b; Latash, 1993; Palaščáková Špringrová, 2011; Vagner et al., 2017; Palaščáková Špringrová et al., 2020). Movements in the CKC allow easier co-activation of muscle chains. Thanks to physiological involvement of muscle chains, which allows even loading of spine structures, the spine straightens. Thanks to physiological co-activation of muscle chains not only joints get into an ideal position but their use in the relevant position or movement is more economical (Poková et al., 2018; Vagner et al., 2018). On the basis of the facts above we consider it appropriate to design a therapeutic programme consisting of ADL motor patterns practised in the CKC and focused on LBP with radicular symptoms.

The aim of the study

Lower back pain (LBP) associated with radicular symptoms is one of the most common diagnoses. There are a number of conventional therapies that are used to treat LBP, but the most effective form of rehabilitation is unknown.

The aim of the study was to find out whether clinical and objective improvement in patients with LBP with radicular symptoms can be reached by means of a 6-week exercise programme consisting of press up ADL motor patterns.

Material and methods

Ten men of 43 ±2.3 years of age on average with a neurological diagnosis of intervebral disc herniation in the L5/S1 segment took part in the study. They were patients of the neurological department of Středomoravská nemocniční a.s. hospital in Přerov. All monitored participants had completed their secondary education. From the perspective of professional anamnesis seven participants labelled their work as a desk job and three of them were manual workers. The probands of the group were physically inactive in terms of the implementation of physical activity in their movement regime (in childhood, adulthood).

In order to maintain homogeneity of the study we determined criteria that all the participants had to meet: the patients underwent neither rehabilitation treatment focused on S1 radicular syndrome, nor rehabilitation treatment focused on problems in the lumbar spine during the last year. The patients never underwent spinal surgery. They did not feel any clinical symptoms of S1 radicular syndrome for more than three months. In order to avoid distortion of the results by chemical symptoms of pain, which patients suffer from in the acute stage, our participants had to undergo infusion therapy before commencing the rehabilitation programme. The infusion included the following analgesics: Novalgin, Myorelaxant Guajacuran and Solumedrol for antiedematous effects with added MgSO4. Infusion therapy was complemented with vitamin B and Milgamma administered orally by a neurologist. The participants underwent infusion therapy before initial examination with a physiotherapist.

Before commencing the exercise programme the patients were screened with MRI (magnetic resonance imaging) for objectivization of structural changes in the disc and the surroundings tissues. It was a standard static projection when the patients were in the supine position with a pillow placed under their knees. Three monitored parameters were selected from the resulting sagittal and transverse T1 and T2 projections: extent of the intervebral disc herniation, oppression of the S1 nerve root and pressure exerted on the dural bag. While two values are typically stated in the description of nerve root compression in the Czech Republic (i.e., with or without nerve root oppression), three variables are mentioned in the description of pressure applied to the dural bag (i.e., without oppression, minimal pressure on the dural bag and oppression of the dural bag). The same radiologist described both initial (Table 1) and final data from MRI examination. In order to avoid distortion of the results, the radiologist was not informed about the course of the study. The patients started the 6-week exercise programme within a period of no more than two weeks from the initial MRI examination.

Table 1. Initial MRI examination

Patient/factors	HE (mm)	NR	DB
Patient 1	3	O	O
Patient 2	7	O	O
Patient 3	13	O	O
Patient 4	7	O	O
Patient 5	4	O	O
Patient 6	5	O	O
Patient 7	17	O	O
Patient 8	10	O	O
Patient 9	13	O	O
Patient 10	9	O	O
Arithmetic mean	8.8	10/10 O	10/10 O

Explanatory notes: HE: hernition extent, NR: S1 nerve root, DB: dural bag, O: oppression.

Before commencing the exercise programme, a physiotherapist carried out an initial clinical examination (Table 2). The following was assessed during the initial clinical examination: pain intensity according to the Visual Analogue Scale (VAS) and paresthesia intensity in the S1 dermatome. We created a special scale for assessment of paresthesia intensity: a numeric paresthesia intensity scale (NPIS). The NPSI works on the same principle as the VAS, thus the patient determines paresthesia intensity on a numeric scale where 0 means no paresthesia and 10 is maximum level of paresthesia intensity. The last evaluated clinical criterion was paresthesia location in the S1 dermatome. Most sources evaluate success of the therapy in patients with radiculopathy caused by intervebral disc herniation according to the VAS, functional limitation (disability) or according to sleep disorders (Ozturk et al., 2006;

Luire et al., 2008; Tosteson, 2008; Steven et al., 2009; Hahne et al., 2010; Kamanli et al., 2010). For that reason, we decided to apply the VAS to the monitored clinical parameters. The second clinical factor that patients in the acute stage complain about the most is parestehia, which significantly increases functional limitation in ADL. So, we decided to include paresthesia intensity and location in our monitored clinical parameters. The patients evaluated clinical symptoms when sitting in the prolonged (1 minute lasting) uncorrected position on the chair without back support.

Table 2. Initial clinical examination: evaluation in the uncorrected position on the chair for 1

Patient/factors	VAS	NPIS	PL
Patient 1	9	7	ED
Patient 2	5	4	CK
Patient 3	0	5	CK
Patient 4	2	7	CK
Patient 5	9	6	ED
Patient 6	7	4	CK
Patient 7	3	3	ED
Patient 8	5	5	ED
Patient 9	1	7	CK
Patient 10	6	4	LSK
Arithmetic average	4.7	5.2	4/10 ED 5/10 CK 1/10 LSK

Explanatory notes: VAS: subjective pain assessment, NPIS: numeric scale of paresthesia intensity in S1 dermatome, PL: paresthesia location in S1 dermatome, ED: entire S1 dermatome, LSK: from lumbar spine to knee joint, CK: caudal from knee to S1 dermatome.

The patients underwent a 6-week rehabilitation programme consisting only of press up exercises in the closed kinematic chain. These press up exercises were based on positions of children´s motor development. The individual motor patterns, which we included in the therapy, were selected according to the activities of daily living of the general population. The patients attended a 45-minute managed rehabilitation once a week. The remaining six days they followed up the exercise programme themselves at home without physiotherapist´s intervention. According to the participants the average time of home workout was 15 minutes. Since they worked out twice a day the total time was 30 minutes per day. During self-therapy they practised only such motor patterns that they trained with a physiotherapist in the managed therapy beforehand. In the course of the rehabilitation programme the physiotherapist accelerated the therapy by adding new motor patterns (Table 3). During the 6-week rehabilitation programme the patients practised almost 6000 repetitions of the press up exercises.

Table 3. Movement programme of press up motor patterns (Palaščáková Špringrová, Vagner)

Exercises	Number of repetitions	Inclusion of motor patterns in the therapy
Press up in the supine position	10	1st therapy
Rotation (L/R hip)	10/10	1st therapy
Press up in the prone position	10	1st therapy
Press up while sitting on the chair	10	1st therapy
Press up from the prone to the all-four position	10	2nd therapy
Press up while putting a foot forwards and standing up (L/R LE)	10/10	2nd therapy
Self-motorisation in the sitting position with both legs bent to a side (L/R)	20/20	4th therapy
Dynamic stretching in the supine position (L/R LE)	20/20	4th therapy

Explanatory notes: L: left, R: right, LE: lower extremity.

At the same time the participants were educated about regime measures, which should have minimized increase in intradiscal pressure, thus also compression of neural structures during ADL. The education included straightening in static positions (sitting, lying, standing up) and avoiding irritation positions (in particular prolonged flexion). The patients were instructed to avoid positions and activities worsening their symptomatology, specifically radiation to the lower extremity. They did not have a set comprehensive rest regime, vice versa they were invited to maintain maximum possible extent of their physical activities, which they were able to practise without any irritation phenomena.

After the end of the exercise programme the patients underwent control MRI examination and final clinical values were determined. The final MRI examination was always planned by two weeks after termination of the exercise programme.

We processed the collected data by means of theoretical methods of inductive reasoning, deductive reasoning and analysis. Next, we applied the methods of mathematical statistics, i.e. arithmetic means (μ), standard deviation (s), median (Me), interquartile range (IQR), with the results recorded in the tables. Despite a limited amount of data statistical normality was not rejected, so we could use the pair t-test (t-test, $p < 0.01$) for comparison of initial and final values of disc herniation extent. Due to non-compliance with data normality we used the Wilcoxon matched-pair test for determination of statistical significance of differences between initial and final measurements of the VAS and the NPIS (Wtest, $p < 0.01$).

The results of the study

The whole monitored group of patients completed the study. During and after completion of the study no medical complications occurred in the participants.

All patients reported statistically significant decrease in pain ($p < 0.01$) and paresthesia (see Table 4). According to the patients pain intensity was on average 4.7 points of the VAS at the beginning of the study. During the final examination the reported pain intensity was 0.9 points of the VAS. It was a statistically significant difference ($p = 0.005$; in round figures). At the beginning of the study reported paresthesia intensity was 5.2 points of the NPIS. At the end of the study paresthesia intensity was on average 0.4 points of the NPIS. It was also a statistically significant difference ($p = 0.006$; in round figures). All monitored patients reported also improvement of paresthesia location (Table 4).

Only 1 from 10 patients reported partial reduction of intervebral disc herniation and it was 35.7%. No reduction of intervebral disc herniation occurred in the remaining nine patients. There was no change in S1 nerve root oppression in any patient. Pressure on the dural bag was reduced in all patients. At the beginning of the study a radiologist identified dural bag compression according to the MRI results in the whole monitored group. At the end of the study the radiologist reported minimal dural bag compression in the whole group of patients (Table 5).

Table 4. Comparison of initial and final clinical examination: evaluation in the uncorrected position on the chair for 1 minute

Patient/factors	VAS 1	VAS 2	NPIS 1	NPIS 2	LP 1	LP 2
Patient 1	9	2	7	1	ED	CK
Patient 2	5	0	4	0	CK	WP
Patient 3	0	0	5	0	CK	WP
Patient 4	2	0	7	1	CK	LPl
Patient 5	9	3	6	0	ED	WP
Patient 6	7	1	4	1	CK	LPl
Patient 7	3	0	3	0	ED	WP
Patient 8	5	1	5	0	ED	WP
Patient 9	1	0	7	1	CK	LPl
Patient 10	6	2	4	0	LSK	WP
Arithmetic mean	4.7	0.9	5.2	0.4	4/10 ED, 5/10 CK, 1/10 LSK	6/10 WP, 1/10 CK, 3/10 LP1
Standard deviation (s)	3.15	1.10	1.48	0.516	×	
Median (Me)	5	0.5	5	0	×	
Interquartile range (IQR)	4.5	1.75	2.75	1	×	
Statistical significance (p)	0.005174 (p < 0.01)		0.00551 (p < 0.01)		×	

Explanatory notes: VAS 1: initial subjective pain assessment, VAS 2: final subjective pain assessment, NPIS 1: initial numeric scale of paresthesia intensity in S1 dermatome, NPIS 2: final numeric scale of paresthesia intensity in S1 dermatome LP 1: initial examination of paresthesia location in S1 dermatome, LP 2: final examination of paresthesia location in S1 dermatome, ED: entire S1 dermatome, LSK: from lumbar spine to knee joint, CK: caudal from knee to S1 dermatome, LPl: lateral preference inventory, 5th metatarsal and 5th finger, WP: without paresthesia.

Table 5. Comparison of initial and final MRI examination

Patient/factors	HE 1 (mm)	HE 2 (mm)	NR 1	NR 2	DS 1	DS 2
Patient 1	3	3	O	O	O	MIN
Patient 2	7	4,5	O	O	O	MIN
Patient 3	13	13	O	O	O	MIN
Patient 4	7	7	O	O	O	MIN
Patient 5	4	4	O	O	O	MIN
Patient 6	5	5	O	O	O	MIN
Patient 7	17	17	O	O	O	MIN
Patient 8	10	10	O	O	O	MIN
Patient 9	13	13	O	O	O	MIN
Patient 10	9	9	O	O	O	MIN
Arithmetic mean	8.8	8.55	10/10 O	10/10 O	10/10 O	10/10 MIN
Standard deviation (s)	4.49	4.67	×	×	×	×
Median (Me)	8	8	×	×	×	×
Interquartil range (IQR)	6.75	7.62	×	×	×	×
Statistical significance (p)	0.3434 (p > 0.01)		×	×	×	×

Explanatory notes: HE 1: initial value of herniation extent, HE 2: final value of herniation extent, NR 1: initial evaluation of S1 nerve root, NR 2: final evaluation of S1 nerve root, DS 1: initial evaluation of dural bag, DS 2: final evaluation of dural bag, O: oppression MIN: minimal compression, **μ**: arithmetic mean.

Discussion

Many studies about conventional treatment of LBP with radicular symptomatology concerning various physiotherapeutic methods were developed. We cannot say for sure which of the physiotherapeutic methods (e.g., low up to high intensity aerobic exercises, stabilization and fitness training, a workout aimed at improvement of spinal flexibility, traction, …) is the most effective. Deviations in classification of disc herniation caused by various imaging techniques, or different ways of classification of disc herniation can result from quite inconsistent

evaluation of effectiveness of conventional therapy (Kamanli et al., 2010; Ozturk et al., 2006; Choi et al., 2010; Mayer et al., 2010; Chou, 2011; Poková et al., 2018). Kamanli et al. (2010) and Ozturk et al. (2006) used traction therapy as a conventional treatment of patients with disc hernation in their studies. In both cases they noted significant improvement in clinical symptomatology in monitored participants. In our study we decided to use press up exercises in the CKC based on ADL of the general population as conventional therapy. The basic principles of workout include pressing up on the acral parts, during which muscle activity is transmitted from peripheral body parts to the centre. When pressing up antagonistic muscle chains are co-activated. Co-activation results in spine straightening and centration of root joints (Palaščáková Špringrová, 2011; Palaščáková Špringrová et al., 2020). We consider press up exercises as a certain type of active traction exercises, the aim of which is automation of acquired motor patterns with the straightened spine based on motor learning in individual ADL.

The group of patients we monitored perceived sensitive symptoms of radicular syndrome, which limited them in performance of ADL, as the primary problem. Our patients considered irritation pain in back and lower extremities with paresthesia as more serious limitation of ADL in comparison with motor deficit associated with S1 radicular syndrome. Pathological loading of the spine in ADL causes immediate pain only in minimum cases. The pain occurs over time following summation of pathological stereotypes, which individuals stop being aware of, and they fix wrong physical activity habits (Doubková et al., 2018). On the basis of the above-mentioned facts, we created a precondition: if individuals´ ADL are set up well, they do not suffer from backache, they can perform their job in an adequate manner and spend leisure time without any limitations. Due to long-lasting asymmetrical loading of the spine pain limiting motor skills of an individual both in job and leisure time develops. According to the Institute of Health Information and Statistics of the Czech Republic in 2017 people suffering from chronic LBP were on average 70 working days unable to work for health reasons. At the average wage of CZK 25,000 per month these people lost approximately CZK 16,000. Unfortunately, we have neither comprehensive data about losses that companies suffered, nor the amount of financial means invested in LBP treatment in the Czech Republic in 2017. We can learn some information on the basis of data from 1998 when Great Britain provided GBP 1.632 million for LBP treatment (recalculation considering inflation rate in 2020: GBP 28.894 million). LBP is not only a medical diagnosis. It is a socio-economic problem of the modern society. It is necessary to focus particularly on LBP prevention and prevent time consuming and many times more expensive treatment (Maniadakis & Gray, 2000; Hayden et al., 2010; Huijnen et al., 2020; Bendíková, 2020; Bendíková & Balkó, 2022).

Summation of unevenly distributed disc loading results in its faster degeneration. Degenerative changes in the disc and the surrounding neural structures are indeed very common and we can take note of them from the second decade of life. However, structural changes in the disc do not have to signify occurrence of radical clinical symptoms (Matveeva et al., 2012; Bendíková, 2020). Recurrent increase in intradiscal pressure caused by pathological loading of the spine during ADL results in increase in pressure exerted on neural structures contained in the dural bag. Excessive flexion motor patterns and static loading of the lumbar spine in semiflectional positions, such as flabby sitting on the chair or working when bending over, increase compression in the dural bag and accelerate occurrence of local inflammation of neural structures in overburdened intraforaminal space. Irritation pain occurs. Increasing pressure on the dural bag increases pain and paresthesia in lower extremities and an individual starts to be significantly limited in ADL. Many people do not solve their LBP problem until the clinical symptoms tie them down in their common life. Limitation of ADL mainly in patients with chronic manifestation of LBP impacts significantly also their psyche, in particular motor control psycho-physiology. As time passes these people create various alternative

motor strategies with the aim not to incite or not to increase pain and paresthesia. As a result, the patients avoid certain movements or positions, including positions decreasing pressure on the dural bag. The individuals identify these "therapeutic movements and positions" on the basis of their fixed motor patterns of ADL and they consider them pathological.

On the basis of the above-mentioned information, we dare to claim that correction of spinal structure loading in ADL should be part of therapy of LBP with radicular symptoms. Therefore, we interconnected physiotherapeutic exercises with ADL that the patients regularly performed. Our exercise programme included motor patterns such as standing up from a chair, rotation from the supine to the lateral and prone position, or dynamic transitions from the prone to the standing position.

Pressing up on the acral parts in the CKC results in spine straightening, which should decrease both intradiscal pressure and pressure exerted on the dural bag. Since it is a progressively arising problem, one-time correction of the spine is insufficient. Therefore, it is important for the patients to fix these new straightened motor patterns in ADL (Palaščáková Špringrová, 2011; Vagner et al., 2018). The right dosing of the therapy is as important as the selection of motor patterns and their implementation in therapy. During the 6-week exercise programme our patients performed approximately six thousand repetitions of press up exercises. The time of primary fixation of motor patterns in everyday workout is 6–8 weeks; in terms of the number of repetitions it deals of ca 4–10 thousand repetitions in case of basal motor patterns, such as ADL of the general population (Palaščáková Špringrová, 2011). In the acute stage it is appropriate to practice the workout several times a day (in our case it was twice a day), thanks to which the patients get used to new movement stereotypes faster and they are earlier able to apply them to ADL. More frequent repetition of press up exercises is beneficial also in terms of clinical symptomatology reduction (Poková et al., 2018; Palaščáková Špringrová et al., 2020). Frequent relief of pain and paresthesia accelerates return to more challenging physical activities and the patients perform their ADL without almost no limitations (Palaščáková Špringrová et al., 2020). Clinical symptomatology reduction has a positive effect also on mental stability of the patients. In our point of view conventional therapy should be aimed at reduction of sensitive symptoms of radical syndrome in the acute stage. As soon as subjective difficulties are reduced or eliminated, patients start to perceive their motor deficit more intensively and they consider it the top of their limitations. So, the sub-acute and chronic stage of the treatment should be focused on restoration of motor functions and physical condition, which helps prepare the patients for return to their usual physical activities in both professional and common life.

In our view press up exercises are very beneficial in LBP therapy for both static and particularly dynamic co-activation (Palaščáková Špringrová, 2011; Poková et al., 2018; Vagner et al., 2018). Static co-activation, which is the basis, is important for patients to correctly perform dynamic motor patterns with a straightened spine. Correct performance of press up exercises on the acral parts leads to muscle co-activation and spine straightening in the static position, e.g., in the supine position; an individual performs a phase movement or dynamic transition to another position, such as to the lateral, while constantly pressing up on the acral parts. In order to boost therapy effectiveness and to accelerate return of the patients to ADL we interconnected press up activities with ADL in our monitored patients. The press up exercises, which they learned to perform under supervision of a physiotherapist, reduced clinical symptomatology and they could be immediately applied to ADL of our participants. We consider dynamic transitions the key factor of LPB therapy. One of the reasons is already mentioned interconnection of the therapy with ADL, when the patients constantly practice dynamics and change in positions. Another reason is maximum possible dynamics of patients who are limited in ordinary activities and forced to avoid dynamic transitions

from individual positions to other ones. Last but not least, static correction is insufficient for application to ADL. Individuals learn how to adjust their body posture in static positions, but they are not able to maintain this adjustment when changing positions.

Research limitations

We monitored changes in the intervebral disc and the surrounding tissues by means of MRI examination, which is considered the best imaging method of the intervebral disc and the surrounding tissues. We chose the standard supine position with a pillow placed under the lower extremities to display neural structures. It was static imaging aimed at the L5/S1 segment, which is primarily used for classification of morphological changes in intervebral discs in the Lp area. From the perspective of biomechanics this position was not ideal in terms of distribution of pressure on intervebral discs. Light kyphotisation of the lumbar spine occurs in this position and intradiscal pressure rises, which can result in dorsal shift of the nucleus pulposus. This position can be one of the reasons why we took note of structural changes in the area of the intervebral disc only in one out of ten patients (Adams et al., 2000; Kerr et al., 2001; Ganesan et al., 2017; Samiei, 2019).

We believe that static imaging by means of MRI examination cannot comprehensively assess morphological findings, which change depending on change of the spine position. McGregor et al. (2002), who proved in his study that under various postural conditions morphological findings in the spine differ, confirms the benefits of MRI examination (McGregor, 2002).

Ozturk et al. (2006), Burgetová et al. (2010), Çitişli & İbrahimoğlu (2015), they all proved in their studies that disc herniation can be reduced by means of conventional therapy (Luire et al., 2008). We agree with the statement that disc herniation can be reduced by means of conventional therapy. However, all the studies mentioned above perform control measurement of disc herniation no sooner than 16 weeks after completion of the treatment. According to the results of our study we do not assume that reduction of disc herniation should be considered a significant factor of recovery in the acute stage of treatment. On the basis of the results of our study we can consider reduction of pressure on the dural bag and its structures as an objective indicator of recovery. In the acute stage of treatment, we should focus specifically on clinical symptoms, because the most appropriate treatment of LBP with radicular symptomatology can be selected only on the basis of them.

Conclusion

Pharmacological treatment, which was indicated to our group of patients, in combination with press up exercises in the closed kinematic chain seems to be effective therapy of LBP with radicular symptomatology. The patients managed to reduce pressure on the dural bag during a 6-week exercise programme, which resulted in reduction or elimination of clinical symptomatology. In the acute stage the patients with LBP with radicular symptoms feel the most limited by clinical symptomatology. We are convinced that conventional therapy should focus primarily on the impact of clinical symptomatology, not on structural changes in the disc and the surrounding tissues. Comparison of initial and final MRI examination in our monitored group of patients did not reveal any statistically significant changes in the herniated disc. We dare to claim that reduction of disc herniation neither signifies primary recovery, nor reduces clinical symptomatology in patients with LBP with radicular symptoms in the acute stage. Reduction of pressure on the dural bag correlated with reduction of clinical symptomatology,

therefore according to our measured results it is a significant indicator of recovery in patients with LBP with radicular symptoms in the acute stage.

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THE EFFECT OF DIFFERENT TYPES OF WARM-UP PROTOCOLS ON THE RANGE OF MOTION AND ON MOTOR ABILITIES OF RHYTHMIC GYMNASTICS ATHLETES AND BALLET DANCERS

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Abstract The aim of this study was to examine the short-term effects of different types of warming up on the range of motion and on motor abilities of rhythmic gymnasts and ballet athletes. Twenty-five athletes participated in this study (11 ballet dancers and 14 rhythmic gymnasts), aged 14,72 ±1,43. All participants followed an intervention consisting of two warm-up protocols, one with static stretching exercises and the other with dynamic warm up protocol. The two protocols were implemented on two different days for one week. Range of motion (ROM) and hop test measurements were carried out before and after each warm-up session. For the statistical analysis, non-parametric (Wilcoxon) tests and Friedman test were used, and the level of significance was set at $p < 0.05$. The results showed that both warm-ups had positive effects on ROM and on motor abilities. After applying both protocols, significant differences were observed in all joints. In conclusion, both types of warm-up routines resulted in almost the same level of improvement in ROM and motor abilities; however, it was observed that after the dynamic warm up there was a slightly increased improvement in motor abilities, but it was not statistically significant.

Key words: rhythmic gymnastics, ballet, range of motion, motor abilities

Introduction

Warming up is a widely accepted form of exercise that precedes almost any sporting activity. The effect of warm up on performance has been examined since the 1930s as to whether and how much it contributes to improving athletic performance. It is a critical factor used by athletes during training and competition to prevent injury and properly prepare the individual for the activity ahead (Bishop, 2003; Bishop & Maxwell, 2009).

Two basic types of warm-ups have prevailed, static and dynamic; this distinction usually refers to the type of stretching exercises which are used (Behm & Chaouachi, 2011). Stretching is commonly used by athletes as a part of their conventional warm- up routine, especially in sports requiring the ability to move fluidly through an extensive range of motion (ROM) (Ferri-Caruana et al., 2020). Several researchers dealt with the static forms of stretching, specifically: the technique (Davis et al., 2005), the duration (Ford et al., 2005), the number of repetitions (Cipriani et al.,2003), program duration (Chan et al., 2001), frequency (Medina et al., 2007) and location of stretching (Decoster et al., 2004). The duration of static stretching (SS) remains debatable. Some researchers argue that the stretching protocol should be done within 15 minutes before the basic training for optimal results, while others lay emphasis on stretching after the training session (Kay & Blazevich, 2012).

The application of SS during the warm-up is likely to affect the performance. Evidence supports that SS may be detrimental if applied immediately prior to performance (Behm & Chaouachi, 2011). In their studies, Cramer et al. (2004) and Cramer et al. (2005), reported that when SS was performed on the dominant leg there was a decline in the torque and motor unit activation as well as reductions in the peak power output in both stretched and non-stretched legs. The inhibitory mechanism of the central nervous system must be at least partially responsible for these observed changes. According to Cramer et al. (2005), decrements in performance after SS are the result of a combination of mechanical and neural factors. Neurologically, SS appears to be related to muscle activation (McHugh & Cosgrave, 2010). In another research by Peck et al., (2014) it has been found that the combination of SS with dynamic exercises, activation exercises or specialized exercises for each sport, reduces or even reverses their negative effect on performance.

Research also reports that there are a few sports with intense SS across the range of motion (Murphy et al., 2010) which demonstrate that flexibility improves statically and contributes to increased performance. For instance, rhythmic gymnastics, where the athletes take different positions of full stretch, martial arts, synchronized swimming, figure skating and ice hockey. SS is regarded as the most suitable for increasing the length of the gluteal tendon and therefore, are the ones that can bring about the highest values to the range of hip flexion (ROM) (Herman & Smith, 2008).

A dynamic warm-up appears to increase both long-term (>5 min) and intermediate performance (>10 s, but <5 min) if athletes are allowed to begin the ensuing procedure in a relatively rested state, due to increased oxygen consumption (Bishop, 2003; Fletcher, 2010). Mechanically, the effects of dynamic stretching (DS) lead to a reduction in the muscle-tendon unit stiffness (Witvrouw et al., 2004). DS and coordination exercises can be incorporated into the warm-up routine. Studies report that DS lead to an increase in static flexibility which is similar to SS (Behm & Chaouachi, 2011). On the contrary, other studies have shown that DS are not as effective in increasing static flexibility as SS. Therefore, more oriented dynamic routines are suggested before training for performance enhancement and tissue health (Behm & Chaouachi, 2011; Herman & Smith, 2008).

Rhythmic gymnastics is an artistic sport like gymnastics, figure skating, synchronized swimming and acrobatics (Fernandez-Villarino et al., 2013). It aims at harmony, the perfect execution of the movement in combination with the

musical accompaniment. Rhythmic gymnastics includes body elements and instrument handling, the performance of which is determined by the International Code of Points (Zasada et al., 2016; Donti et al., 2014).

A successful ballet career requires the dancer to be both flexible and strong. The basic ballet movements are the plie and the turnout. These movements are the basis from which a lot of other movements, such as jumps and bouncing (Grossman, & Wilmerding, 2000). Dancers are known to have a good physical condition and shapely bodies, as well as a wide range of motion in their joints, which is a great advantage in many types of dances (Turner & Wainwright, 2003; McCormak, 2004). Flexibility is an important aspect of good physical condition in dancers and a high level of flexibility is necessary to meet the choreographic demands made on them today.

Rhythmic gymnasts and ballet dancers are all about flexibility and must also have a wide range of motion especially in the hip joints (Donti et al., 2014; Wyon et al., 2013). The aim of this study was to examine the short-term effects of different types of warm-ups on the range of motion and on motor abilities of rhythmic gymnastics and ballet athletes. Such information may assist in determining the applications and limitations of various stretching techniques and programs in flexibility-trained athletes.

Materials and Methods

Study design

To achieve the objectives of this study, a prospective, observational study was carried out in which a convenience sample of 25 female ballet dancers and rhythmic gymnasts were analyzed. The following inclusion criteria of the target population were used: (1) being a ballet dancer with more than 7 years of experience; (2) being a rhythmic gymnastics athlete with more than 7 years of competitive participation. The duration of each testing lasted a week, more specifically, 3 days of the week with 2 days of resting between each phase. The purpose of the first day was to familiarize the subjects with the process and the requirements of the intervention; during the second phase, the athletes performed the protocol with the static stretching exercises; during the third phase they performed the protocol with the dynamic stretching exercises. The warm-up protocol included exercises on the barre, in the center and dynamic elements with rotation of approximately 40 minutes' duration. Prior and after each warm-up protocol, ROM and motor abilities were measured. The study was conducted according to the Declaration of Helsinki and was approved by the Ethics Committee of the School of Physical Education and Sport Science Aristotle University of Thessaloniki (GRI-2017-18764).

Participants

A total of thirty female participants volunteered to participate in the study: fifteen classical dancers from a private dancing school with more than 7 years of ballet experience and fifteen rhythmic gymnasts with more than 7 years of participation. The young girls did not have any musculoskeletal problems or any serious injury for one month prior to their participation. Five female athletes who did not complete the study procedure were excluded. The final sample for evaluation was 11 rhythmic gymnasts and 14 ballet dancers, aged 13 to 17. The female athletes participated in the research after obtaining written consent from their parents and oral consent from the examiners. All participants received introductory comments about the rationale of the research, the utilization of the data, the themes, and the objects to be pursued. Verbal instructions regarding the research process were also given.

Prior to the data collection, the participants' parents provided a signed consent form allowing their child's participation in the study.

Anthropometric measurements

The weight and height of the female athletes was measured using a Microlife WS80 electronic scale and a SECA216 height meter, respectively. The participants' BMI was calculated (kg/m^2). Body fat percentage [FM (%)] was estimated using four skinfolds (triceps, supra-iliac, abdomen, and thigh), according to the equation, described by McArdle (Katch, & Mcardle, 1973).

Flexibility Assessment

In the study, ROM during hip flexion, knee flexion, and dorsiflexion of the ankle joint was examined by an experienced examiner. All measurements were made with the help of the Myrin goniometer, according to the method introduced by Ekstrand et al. (1982). We collected the data from the best performance. All measurements, apart from the ankle dorsiflexion, were performed on the floor on a soft mattress.

The subject was placed in supine position and the leg was lifted (hip flexion and keeping the knee extended and ankle in neutral position) the other leg as well as the pelvis were stabilized by the examiner. The subjects were asked to actively lift the limb to reach the maximum ROM of the leg to be tested. An experienced examiner held and pressed the limb of the subject from neutral to extreme position, as defined by the American Academy of Orthopedic Surgeons which recorded the value of joint range of motion in degrees. The Myrin was placed on the greater trochanter (Noyes et al., 1991). This passive movement of the joint in its extreme position was performed to the point at which the examiner felt the maximum resistance of the lengthening muscle groups, as determined by Ferber et al. (2002) without the subject feeling discomfort or muscle pain.

To measure the quadriceps stretch it is recommended that the subject lie in prone position with the lower extremity in a neutral position. The examiner stands beside the subject, at the side of the leg that will be tested. One hand should be on the lower back, the other holding the leg at the heel. Passively flex the knee in a slow fashion. The heel should touch the gluteus maximus. In order to measure the range of the flexion, the same procedure is followed as before.

Ankle dorsiflexion ROM was measured using a weight-bearing lunge facing a wall. The weight-bearing lunge was performed in a standing position with the heel in contact with the ground, the knee in line with the second toe, and the big toe 10 cm away from the wall. Participants were asked to lunge forward, directing their knees toward the wall (in line with the second toe) until their knees touched the wall. Once the knee was not able to touch the wall, the foot was moved gradually toward the wall until the knee touched the wall with the heel in contact with the ground. While the subject maintained her maximal dorsiflexion position, a standard goniometer was aligned with the floor and through the shaft of the fibula by visually bisecting the lateral malleolus and the fibular head (Konor et al. 2012).

Hop tests

Specific hop tests were implemented to check the stability of the knee joints, which are mainly used in the rehabilitation of people after injury. Additionally, these tests also assess strength and balance (Noyes et al. 1991). Dance requires bounces and jumps, so balance tests are of particular interest when evaluating dancers.

We evaluated four one-legged function tests: single hop and triple hop for distance, cross-over hop and 6 meters in a given time. The four tests are illustrated in Figure 1.

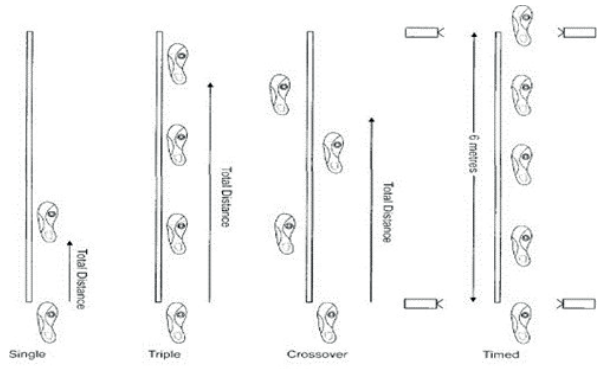

Figure 1. Hop tests

A 6-m long, 15-cm wide line was marked on the floor, along the middle of which was a standard tape measure, perpendicular to the starting line. Subjects performed 2 trials of each hop test, and the best performance was used for the evaluation. Both limbs were tested, and no restrictions were given to subjects regarding the use of arm movement.

For the single hop, athletes were required to hop forward as far as possible along the line of the tape measure and land on the same limb. The triple hop involved participants performing 3 consecutive maximal hops along the line of the tape measure. In the crossover hop test, the time needed to cover a 6 m distance hopping a 15-cm-wide line alternatively from one side to the other, was used for evaluation. In 6-m timed hop, participants hopped on one leg forward to cover a 6-meter distance as quickly as possible and the time they needed was measured. Distance was measured from the starting line to the rear of the foot upon final landing.

Warm-up protocol

According to the warm-up protocol, the two groups had to perform ballet barre and center exercises adapted to static and dynamic stretching (Table 1). The type of training method of this study was based on the Vaganova system, which was a classical ballet technique named after its creator, the Russian ballet dancer (Vaganova, 2012).

Table 1. Warm-up protocol: the exercises performed by the groups are presented in detail below

Centre	Barless execution mode with the same exercises STATIC WARMUP	Barless execution mode with the same exercises DYNAMIC WARM UP
Plié	Standstill for 15 sec in the 4 positions of feet 3 reps in each position	3 reps in the 4 positions of feet
Battement tendu	Standstill for 15 sec in each position for the exercise performance	3 reps in each position
Battement jete	Standstill for 15 sec in each position for the exercise performance	3 reps in each position
Rond de jambe par térre	Slow execution of the exercise staying 15" in each position	Fast execution 3 reps in each position
Battement Fondu	Slow execution of the exercise staying 15" in each position	Fast execution 3 reps in each position
Rond de jambe en l' air	Slow execution of the exercise staying 15" in each position	Fast execution 3 reps in each position
Battement frappé	Standstill for 15 sec in each position for the exercise performance	3 reps in each position for the exercise performance
Adagio	Slow execution of the exercise staying 15" in each position	Fast execution 3 reps in each position
Grand Battements	Slow execution of the exercise staying 15" in each position	Fast execution 3 reps in each position
Jumps & Leaps		
Echappe chaute	3 reps after landing still in the plie position for 10 sec	3 reps in each position
Assemble I	3 reps after landing still in the plie position for 10 sec	3 reps in each position
Assemble II	3 reps after landing still in the plie position for 10 sec	3 reps in each position
Petit Jetes	3 reps after landing still in the plie position for 10 sec	3 reps in each position
Grand jete	1 rep after landing still at plie for 10 sec	3 reps in one try extending different leg each time

Data analysis

Statistical analysis was performed using the statistic packet SPSS version 26.0. The quantitative variables were evaluated as mean ± standard deviation (SD). At baseline all dependent variables, regarding the hop tests and range of motion, were found to be not normally distributed using the Kolmogorov-Smirnov tests of normality. For this reason and because of the small number of participants, we applied non- parametric methods. Wilcoxon test was used to evaluate variables' differences, between baseline and after intervention. When the independent variable had three groups Friedman test was used for the analysis. Statistical significance was reported at $p < 0.05$.

Results

Anthropometric and physiological characteristics of ballet dancers and rhythmic gymnasts group are presented in Table 2.

Table 2. Physical characteristics of ballet dancers

	Ballet dancers (n = 11)	Rhythmic gymnasts (n = 14)
Age (years)	15.4 ±1.2	13.86 ±1.03
Weight (kg)	52.1 ±5.7	36.0 ±7.2
Height (cm)	1.60 ±0.05	1.43 ±0.86
Body Fat	9.91 ±0.55	7.71 ±2.14
Body mass index (kg/m^2)	20.13 ±1.8	17.41 ±1.86
Data are mean & standard deviation (SD)		

Regarding the ballet group, significant improvements were observed after the intervention of SS warm up in the single hop test (Figure 2) and triple hop test (Figure 3), $Z = –2.934$ & $p < 0.05$ and $Z = –1.987$ & $p < 0.05$ respectively. Similar results were also observed before and after the intervention of DS warm up in the single (Figure 2) and triple hop test (Figure 3), $Z = –2.938$ & $p < 0.05$ and $Z = –2.401$ & $p < 0.05$ respectively.

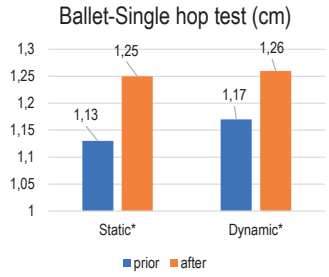

Figure 2. Single hop test prior and after the interventions of SS and DS warm up protocols
*p < 0,05.

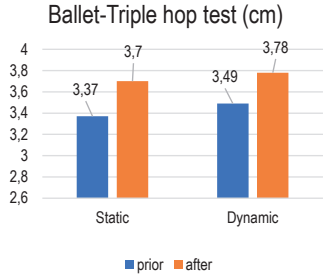

Figure 3. Triple hop test prior and after the interventions of SS and DS warm up protocol

Significant differences were not observed prior and after the intervention of SS warm up in the crossover hop test (Figure 4) and 6m hop test (Figure 5), Z = –0.535 & p > 0.05 and Z = –1.826 & p > 0.05 respectively. Similarly, there were no significant differences before and after the intervention of DS warm up in the crossover (Figure 4) and 6m hop test (Figure 5), Z = –0.711 & p > 0.05 and Z = –0.653 & p > 0.05 respectively.

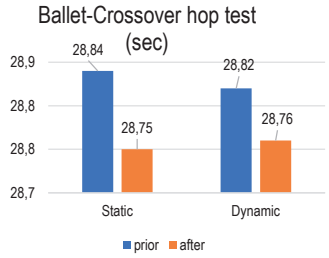

Figure 4. Crossover hop test, prior and after the interventions of SS and DS warm-up protocols

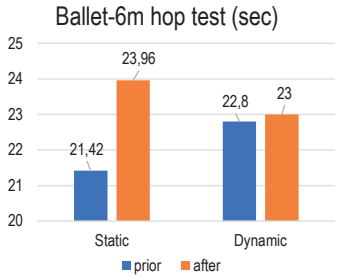

Figure 5. 6m hop test, prior and after the interventions of SS and DS warm-up protocols

Regarding the rhythmic gymnastics group, significant differences were not observed prior and after the intervention of SS warm up in the single hop test Z = –1.455 & p > 0.05 (Figure 6). However, significant improvement was observed in the triple hop test, Z = –3.110 & p < 0.01 (Figure 7). Before and after the intervention of DS warm up significant improvement was observed in the single hop test, Z = –3,299 & p < 0.001 (Figure 6), and no differences in triple hop test, Z = –1,689 & p > 0.05 (Figure 7).

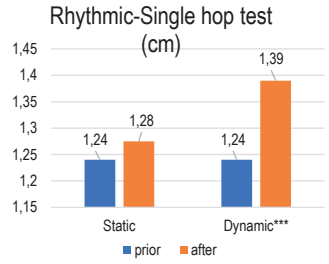

Figure 6. Single hop test, prior and after the interventions of SS and DS warm-up protocols
***p < 0,001

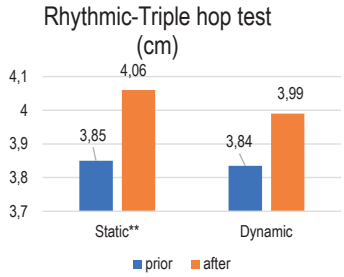

Figure 7. Triple hop test, prior and after the interventions of SS and DS warm-up protocols
**p < 0,01

Significant differences were not observed prior and after the intervention of SS warm-up in the crossover hop test (Figure 8) and the 6m hop test (Figure 9), with Z = –0.094 & p > 0.05 and Z = –1.036 & p > 0.05 respectively. Similarly, there were no significant differences before and after the intervention of DS warm-up in the crossover (Figure 8) and the 6m hop test (Figure 9), with Z = –1.783 & p > 0.05 and Z = –0.126 & p > 0.05 respectively.

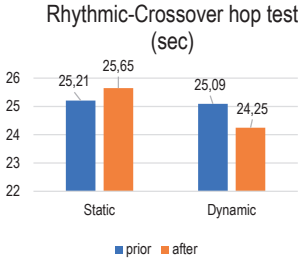

Figure 8. Crossover hop test, prior and after the interventions of SS and DS warm-ups

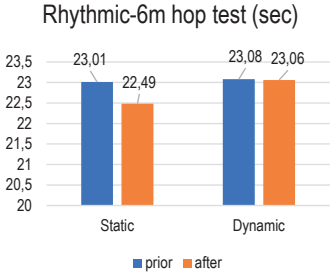

Figure 9. 6m hop test, prior and after the interventions of SS and DS warm-ups

The ROM (biceps, quadriceps, ankle joint) was assessed before and after SS and DS warm-ups. Friedman test was used to estimate the potential differences between them. Regarding the ballet group, the results drawn from the measurements showed significant improvements after both interventions in the biceps, X2 = 15.805 & p < 0.001. From these measurements significant improvements were also found after both interventions in quadriceps, X2 = 6,348 & p < 0.05, and in ankle joint, X2 = 11.474 & p < 0.001 (Figure 10).

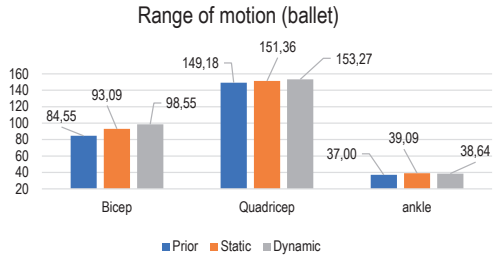

Figure 10. Range of motion assessment before and after SS and DS warm- ups, for ballet group

Similarly, the results from the rhythmic group showed significant improvements after both interventions in biceps, $X2 = 24.500$ & $p < 0.001$, with range of motion in biceps being significant grater after the DS warm-up than after the SS warm-up, $Z = –2.929$ & $p < 0.01$. Significant improvements after both interventions were also found in quadriceps, $X2 = 12.000$ & $p < 0.01$, and in ankle joint, $X2 = 9.250$ & $p < 0.05$ (Figure 11).

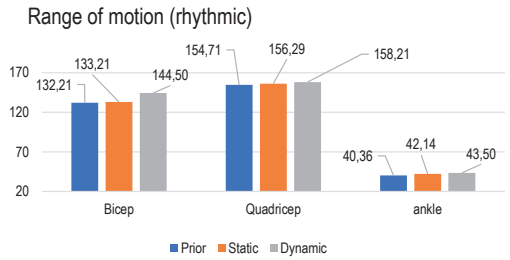

Figure 11. Range of motion assessment before and after SS and DS warm-ups, for rhythmic group

Discussion

The purpose of this study was to examine the effect of two different forms of warm-up protocols on joint mobility and motor abilities of female rhythmic gymnastics and ballet athletes. The results of the present study, show that joint mobility of ballet and rhythmic gymnastics athletes as well as their motor abilities improved with both warm-up protocols. Specifically, in the ballet group, an increase in joint mobility was observed in all joints that were measured after the application of both protocols. The rhythmic gymnastics group showed an increase in joint mobility in the extension of the hip and ankle joint after the application of both protocols. However, an increase in knee flexion was observed only after the dynamic warm-up in both groups.

The results of this study cannot be directly compared with previous research. Nevertheless, there are some studies that raise the same issues as this project but with different populations or with a different warm-up protocol (DiCagno et al., 2010; Samson et al., 2012). A statistically significant difference was found in all joints with both protocols. Moreover, both warm-up protocols seem effective in terms of joint mobility with a statistically significant difference for both groups.

DiCagno et al. (2010) in their research with thirty-eight female rhythmic gymnasts, support that when SS is included in the warm-up, it has a negative effect on technical jumps by 7% and a reduction in vertical jumps. However, having used the hop tests in the warm-up, their results showed an increase after SS and an increase in contact time. Examination of our data from the hop test agree with this study since they showed an increase in contact time and distance after measuring single leg support jumps.

After the general warm-up and SS for up to 30 sec, a specific warm-up combination of SS and DS was applied and an increase in joint mobility was observed (Samson et.al, 2012). It has been found that the combination of SS with DS, activation exercises or specialized exercises for each sport, reduces, or even reverses their negative effect on performance (Peck et al., 2014). Similarly, Perrier et al. (2011) suggest that SS and DS are equally effective in improving hamstring flexibility performance. Thus, DS may be particularly beneficial in sports requiring a combination of flexibility and explosive force because it appears to provide the greatest performance benefits without sacrificing acute flexibility in the process. Lima et al. (2016) also examined the combination of SS and DS on strength and muscular fatigue between ballet dancers and resistance trained women after testing them with sit-and-reach and quadriceps ROM tests. Both groups improved similarly with pre fatigue tests compared to posttests following both stretching types. The findings of our research agree with these studies, since the results of functional tests and joint mobility combined with the warm-up protocol had positive effects on both groups.

Several of our finding's present similarities with the study of McNair and Stanley (1996) who studied the effect of SS. The results showed a beneficial effect on people engaged in sports activities. Additionally, it was observed that, after SS, the joint mobility of the ankle joint increased. In our research, an increase in the ankle joint was also observed, although the difference was not statistically significant; in the ballet group it was slightly greater after both types of warm up whereas in the rhythmic gymnastics group it was slightly greater only after the dynamic warm-up.

A significant amount of research shows that in various parameters of maximum performance, the short-term effect of SS in the warm-up is negative (Behm & Kibele, 2007; Caruana et al., 2020). For that reason, it is recommended that SS be avoided before physical exercise that requires speed, power, and muscle strength. Caruana et al. (2020) defined the long-term effect of the dynamic ROM stretching technique and SS on vertical jump performance in female acrobatic gymnasts. They found that when the long-term dynamic ROM stretching exercises are applied during warm-ups, they result in a slight increase in vertical jump performance compared to SS.

Also, Lima et al. (2016), suggested that stretching decreases hamstrings strength, similarly in ballet dancers and resistance-trained women, with no differences between modes of stretching. Regarding the outcomes of the present research, the rhythmic gymnastics team presented negative results after the dynamic warm-up, specifically in the hop test, the cross over test and the 6-meter test, in terms of time performance. A dynamic warm-up does not affect sprint performance but may reduce explosive power. Additionally, the female athletes obtained a negative result, possibly due to fatigue. Bacurau et al. (2009), used 20 min of ballistic stretch activities and reported a 2.2% decrease in leg press 1-RM and a 5%–7% decrease in knee flexion and extension 1-RMs, respectively (likely fatigue related).

Faigenbaum et al. (2005) after three different SS warm-up protocols, observed a decrease in the vertical jump by 6.5% and 1.9% in the long jump, as well as a decrease in flexibility by 2.6% after all three SS warm-ups. Research suggests that improvement in lower extremity peak strength and power can occur after years of flexibility training (Behara, & Jacobson, 2015; Hartmann et al., 2015).

Conclusions

Our findings demonstrate that the warm-up protocols had a positive effect on ballet dancers and rhythmic gymnasts. However, it was observed that the SS warm-up had a better application in ballet dancers whereas, the DS warm up had a greater impact on rhythmic gymnasts. Possibly with a larger sample the results would be more strengthened. The utilization of hop tests may be of particular interest for further research in the assessment of dancers.

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CORE STRENGTH AS A PARAMOUNT CONTRIBUTOR FOR POTENTIAL UPPER LIMB ISOMETRIC STRENGTH – A CORRELATIONAL STUDY

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Abstract It is believed that a strong core will enable an athlete to effectively transfer forces from the lower extremities through the torso to the upper extremities. Control of the shoulder girdle force is important for the proper function of the upper extremities, although stabilising forces from the trunk and pelvis are also important. The purpose of this study is to determine the association between shoulder isometric push-up/pull-down strength and isometric strength of the abdominal muscles. Using the HUR Rehab-Line 5310 & 5120, isometric upper limb and core strength was measured. The statistical analysis revealed a moderate but significant positive association between the strength of the back muscles and isometric push-ups. Additionally, there was a weak and significant connection between isometric push-ups and abdominal strength. The study therefore draws the conclusion that there is a link between isometric upper limb performance and core musculature strength/stability. The abdominal and back muscles' isometric strength is closely tied to the isometric push-up, which is attributable to the contraction of the Pectoralis Major, Deltoid, and Triceps Brachii. The only muscle group identified to have a substantial and positive correlation with isometric pull-down strength is the abdominal muscles.

Key words: core strength, female athletes, push-up, pull-down, isometric strength

Introduction

The muscles in the core are in control of generating force, which leads to motion in the joints of the extremities (Rivera, 2016). For the functioning of the extremities and the transfer of force, a sturdy base is necessary, which the muscles of the core provide (Shinkle et al., 2012). The pelvic floor and hip girdle muscles serve as the bottom of the

lumbo-pelvic hip complex, the diaphragm serves as the roof, the abdominals and obliques are in the front, and the paraspinals and gluteals are in the rear (Akuthota & Nadler, 2004).

Engaging the gleno-humeral and trunk muscles simultaneously is necessary for any overhead sport or training exercise. When engaging in various sports, such as throwing or running, the trunk's stability is crucial for generating the most force and minimising the strain on the joints (Krause et al., 2018). A lack of core stability has been associated with injuries to the shoulders and elbows (Burkhart et al., 2003). The forces and biomechanics of upper-extremity movements can be altered by aberrant neuromuscular control in any link in the chain, according to the kinetic chain theory (Kibler et al., 2006; Silfies et al., 2015).

It is believed that a strong core will enable an athlete to effectively transfer forces generated by the lower extremities through the torso to the upper extremities (Behm et al., 2005; Cissik, 2002; McGill., 2006). The disruption of energy flow caused by a weak core is thought to impair athletic performance and raise the possibility of damaging a muscle group that is already underdeveloped or weak. By providing a basis for higher force/power production in the limbs, trunk stability has been shown to enhance athletic performance. Control of the shoulder girdle force as well as trunk and pelvic stabilising force are necessary for the upper extremities to function perfectly (Burkhart et al., 2003). To get the best core stability, local and global stabilisers are employed. Large global stabilisers like the erector spinae, latissimus dorsi, and hip abductors provide the strength and stability required for upper extremity activities (Sciascia & Cromwell, 2012). If the trunk and pelvis complex is unstable, the shoulder and elbow muscles will need to work more to produce energy. The kinetic and kinematic interplay of the pelvis and trunk was assumed to affect the movement of the shoulder, elbow, and wrist during overhead motion (Ben Kibler, 1998).

Thus, the aim of this study is to evaluate the relationship between shoulder isometric push-up/pull-down isometric strength and core musculature isometric strength. Further, this study aims at quantifying the relationship between upper limb and core strength.

Methods

Participants

67 female athletes of various sports namely handball, volleyball, basketball, badminton etc. were approached and recruited for participation in the study. The sample size was estimated using statistical G power 3.1.9.7 software. The power of the study was set to 80% ($\beta = 0.84$). and the level of significance at 0.05. Those females aged between 18–25 years were included in the study that had been playing for the last 2 years and involved in training with a frequency of at least 3 sessions per week. Subjects with any recent injury or musculoskeletal pain in upper limb were excluded. Out of 67 female athletes, 4 were excluded based on exclusion criteria and 3 participants dropped out during the testing. Finally, data of 60 female overhead athletes (Age 20.72 ±2.043, height 1.67 ±0.081 m, and weight 61.03 ±.07.94 kg) were recorded. All procedures were approved by the Ethics Committee of Guru Nanak Dev University, Amritsar, Punjab (No. 37/HG, Dated 12/1/2022).

Procedure and Data Collection

The subjects after reviewing for inclusion and exclusion criteria were asked to fill the consent form before undertaking the procedure. For the anthropometric data, a stadiometer was used to examine the height and

digital weight machine was used to measure the weight. Participants were asked to warm up for 5–10 minutes. The following measurements were taken in kilograms.

Isometric Abdomen/Back Strength by HUR Rehab Line 5310-Abdomen/Back Rehab

Equipment adjustment: Separate performance recorder device was attached to the machine. The distance between the seat and the rollers was adjusted, allowing for a suitable exercising position for all participants. The rear foot of the seat was lifted by the black handles and the seat was moved to the desired position. Height of the seat was adjusted by lifting it from the back with both hands so that the lever arm cushion was above the chest.

1. Abdomen exercise: The lever arm was held against the player's chest while she was seated. Exercise was done by holding the roller gently in the hands and pulling the lever arm downward with the abdominals.

2. Abdomen lLeft exercise: The participant sat onto the left-facing seat in a sideways position. Pushing the lever arm downward and sustaining resistance throughout the return movement required the athlete to use her abdominal muscles.

3. Abdomen right exercise: The player sat on the seat with her right side up. Pushing the lever arm downward and maintaining resistance throughout the return movement required the athlete to use her abdominals.

4. Back exercise: The player was seated so that the lever arm rested against her shoulder blades. Her arms were crossed on her chest as she exercised by pressing the lever arm down with the muscles in her lower back. (HUR Analogue Machines Owner's manual (3310 / 5310 Abdomen/Back 2021) (Figure 1).

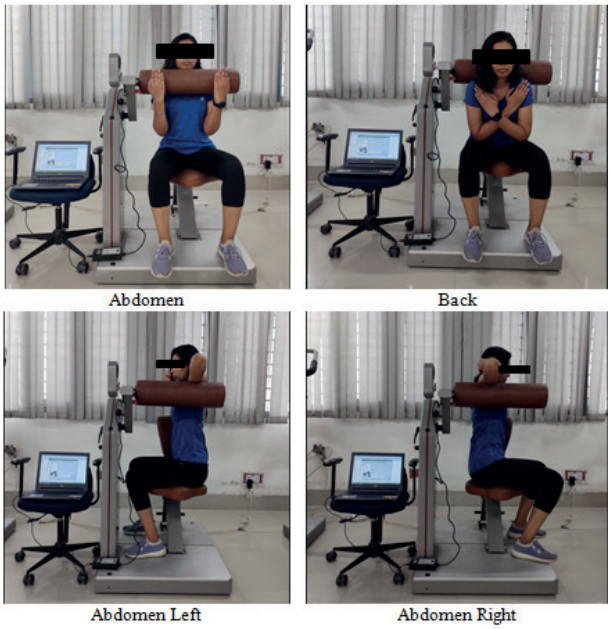

Figure 1. Subject Position for Measurement Isometric Abdomen/Back Strength by HUR Rehab Line 5310-Abdomen/Back Rehab

Isometric Shoulder Strength by HUR Rehab Line 5120-Push Up/Pull Down Rehab

Player was instructed to do proper stretching of trapezius and shoulder girdle muscles prior to testing. Separate performance recorder device was attached to the machine. Then height of the seat was adjusted regarding players height and safety belt was attached.

1. Push Up exercise (Pectoralis Major, Deltoid, Triceps Brachii): The exercise was carried out by the player lifting the lever arms up with their hands while leaning against the back support and maintaining straight wrists.

2. Pull down exercise (Biceps Brachii, Latissimus Dorsi, Infraspinatus, Teres Major and Teres Minor): The exercise was carried out by the player by pulling the lever arms down with their hands. (HUR Analog Machines Owner's manual (3120 / 5120 Push Up / Pull Down), 2021) (Figure 2).

Data was collected by asking players to apply their maximum force at a specific angle for a predetermined amount of time. The participant was given three tries with ten seconds of rest in between each trial. The best measurement, which took into account the measured force, actual force, and actual torque during the test, was taken into consideration.

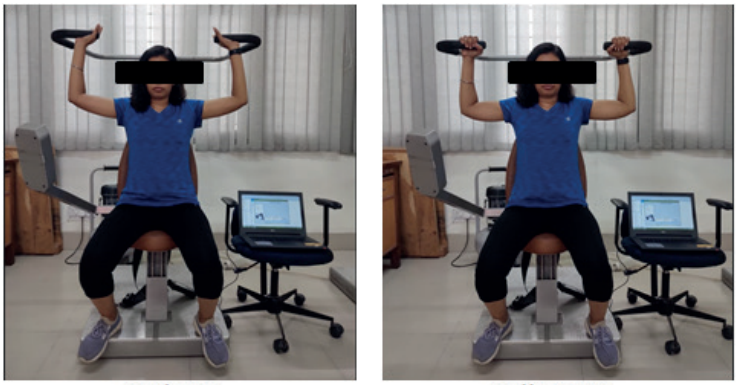

Figure 2. Subject Position for Measurement of Isometric Shoulder Strength by HUR Rehab Line 5120-Push Up/Pull Down Rehab

Statistical Analysis

IBM Statistical Package for Social Sciences 26 (SPSS) software was used for analysis. The arithmetic mean and standard deviation were calculated to prepare a summary of statistics. The data was found normally distributed by Shapiro-Wilk test. Therefore, Pearson's Correlation Test was used to analyse the relationship between upper limb and core parameters. The level of significance was set at 0.05.The classification of the correlation coefficient is as follows: 0 = no correlation, 0 <| r |> 0.2 = very weak correlation, 0.2 < | r |> 0.4 = weak correlation, 0.4 < | r |> 0.6 = medium correlation, 0.6 < | r |> 0.8 = strong correlation, 0.8 < | r | > 1 = very high correlation, 1 = perfect correlation.

Results

Descriptive analysis of anthropometric measurements was done (Table 1). The data was found normally distributed and Pearson's correlation test was used to analyse relationship between Abdomen (kg), Back (kg), Abdomen-Left (kg), Abdomen-Right (kg), Push Up (kg) and Pull Down (kg).

Table 1. Descriptive Statistics of Parameters

Parameters (kg)	Mean	Standard Deviation
Abdomen	132.115	17.64
Back	177.940	44.04
Abdomen-Left	146.440	30.53
Abdomen-Right	154.670	35.61
Push-Up	263.840	38.85
Pull-Down	220.780	37.70

The analysis showed significant positive moderate correlation between isometric push-up and back muscle strength. Further, there occurred a positive but weak correlation between isometric push-up and abdomen strength. This suggests that abdomen and back muscle strength ultimately influences the multi-joint push up movement in upper limbs. The oblique's and the push-up strength were found to have insignificant and weak correlation (Table 2).

Table 2. Pearson's Correlation Coefficient between Isometric Push up Strength and Core parameters

CORE PARAMETERS	Isometric PUSH UP Strength (kgs)	
(ISOMETRIC)	Level of Significance	Correlation Coefficient
Abdomen (kgs)	0.004*	0.369
Back (kgs)	0.000*	0.458
Abdomen Left (kgs)	0.080	0.228
Abdomen Right (kgs)	0.200	0.167

(* denotes significant p-value at 0.05 level)

Also, the result of the study showed significant positive and moderate correlation between isometric pull down and abdomen muscle strength. Surprisingly, the obliques of only left side i.e. abdomen-left isometric strength showed significant but weak correlation with isometric pull-down strength (Table 3). Hence, the results suggest that there exists a positive correlation between the potential strength of upper limbs and the core musculature strength.

Table 3. Pearson's Correlation Coefficient between Isometric Pull Down Strength and Core parameters

CORE PARAMETERS	Isometric PULL DOWN Strength (kgs)	
(ISOMETRIC)	Level of Significance	Correlation Coefficient
Abdomen (kgs)	0.000*	0.468
Back (kgs)	0.111	0.208
Abdomen Left (kgs)	0.027*	0.286
Abdomen Right (kgs)	0.090	0.221

(* denotes significant p-value at 0.05 level)

Discussion

The aim of this study was to evaluate relationship between shoulder isometric push-up/pull-down and core musculature isometric strength.

The study found a significant positive correlation between the strength of the abdominal/back muscles and the comparable upper limb (push-up/pull-down) isometric strength. The same can be explained by previously published research on how trunk stability affects the functioning of the distal extremities. It has been demonstrated that trunk stability enhances athletic performance by laying the foundation for the limbs to produce more force and power (Willardson, 2007). For a range of sport-specific movements, including forehand and backhand strokes in tennis, and overhead throwing in baseball, the synergistic interaction between the muscles of the core and limbs has been observed (Zemkova, 2018; Ellenbecker and Roetert, 2004; Aguinaldo et al., 2007; Stodden et al., 2001). Glenohumeral and trunk muscles must be activated simultaneously for any overhead sport or training task. In a variety of actions, from throwing to sprinting, trunk stability is crucial for generating the most force and minimising joint load (Krause et al., 2018).

Core stability and upper limb strength are moderately correlated (Ahmed et al., 2022). When moving their upper or lower limbs, people with enough core strength employ their trunk muscles in a feed-forward manner (Brumitt & Dale, 2009; Willardson, 2007; Arora et al., 2021). When the extremities begin moving, the body prepares for the likelihood of spinal instability, which initiates this feed-forward process (Richardson, 2004). In some isometric shoulder movements, the trunk muscles are engaged. Standing unilateral horizontal shoulder abduction and bilateral shoulder extension both result in the greatest activation of the trunk muscles. When performing unilateral horizontal abduction, the multifidus and longissimus muscles (maximum activation on the contralateral side) were most active, however when performing bilateral shoulder extension, the external obliques and rectus abdominis muscles were most active (Tarnanen et al., 2008). While simultaneously enhancing the power and endurance of peripheral joints and enabling energy to be transported to distal segments, strong core stabilisation lowers pressure on the spinal column (Hazar et al., 2017).

Hodges and Richardson (1997) stated that trunk muscle action, in particular the activation of the transversus abdominis and multifidus, occurs prior to the initiation of arm motion to aid in stabilising the surrounding joints, controlling position within the base of support, and advancing with smooth upper body movements on a stable base (Arora et al., 2021). Due to the principle of force production, transfer, and control of force and motion to the terminal segment in integrated kinetic chain activities, the musculature of the trunk is also crucial for controlling the motions of the upper limbs and maximising the production of strength in the shoulder (Kibler et al., 2006); this energy production is best absorbed when the muscles of core and extremities are strong (Lattimer et al., 2018; Oliver et al., 2013; Guirelli et al., 2021).

While deep muscles are small and control intervertebral motions, superficial muscles move the lumbar vertebrae, allowing for big arm movements. According to these findings, regional muscles such as the transversus abdominis and deep multifidus fibers are intersegmental motion stabilisers. When maintaining posture is hampered by voluntary arm movement, the direction of the shoulder's movement determines if the deep and superficial Multifidus fibres are activated. When the shoulder is flexed voluntarily, deep and superficial fibres exhibit feedforward activity in relation to the deltoid, suggesting that multifidus activation occurs before deltoid activation (Abiko et al., 2015).

Additionally, Tarnanen and colleagues hypothesised that dynamic unilateral upper limb workouts differed in how they stimulated the muscles on the ipsilateral and contralateral sides. The obliquus externus abdominis,

longissimus, and multifidus muscles were shown to have the most changes between the ipsilateral and contralateral sides following shoulder flexion and extension exercises, whereas the rectus abdominis muscles had the least differences. Additionally, by generating torque in the torso, standing upper-limb workouts strengthen the core and back muscles. By changing upper limb postures (lever arm) and movement direction (pushing vs. pulling), one can create selective core muscle engagement (Tarnanen et al., 2012).

Practically, cross-country skiing, rowing, and tennis are just a few examples of activities and sports that demand for controlled use of the back and abdominal muscles while using the upper limbs (Tarnanen et al., 2012). In a study of 20 university-level fencers, a 6-week core-strengthening regimen resulted in significant gains in agility and upper-limb strength as judged by the 1-minute push-up test (Paul, 2019). Additionally, it has been noted that basketball players perform better with their upper extremities when they have a higher level of core activation. When compared to no core exercise, there was a significant improvement in the one arm hop test and modified upper quarter Y balance performance scores with intentional core activation (Arora et al., 2021).

Therefore, it can be safely suggested that strong core musculature has a positive influence on the potential strength of upper limb in female athletes indulging in overhead sports.

Conclusion

According to the study's findings, there is a relationship between core muscle strength and stability and isometric upper limb performance. The isomteric strength of the abdominal and back muscles is closely related to the isomteric push-up strength that is attributed to contraction of the pectoralis major, deltoid, and triceps brachii. The only muscle group identified to have a substantial and positive correlation with isometric pull-down strength is the abdominals. T the left side's oblique (internal and external) revealed a significant correlation with the isometric pull down strength. Therefore, this research reveals that core strength and stability are two such criteria that need to be measured and addressed for successful and efficient performance in overhead athletes. Furthermore, attention should be directed into getting the core muscles prepared to provide the most stability at peak performance if any player, despite consistent and rigorous upper limb strength training, exhibits no improvement in upper limb strength and power. This is likely to benefit the athletes in improving their game.

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INFLUENCE OF BEETROOT SUPPLEMENTATION ON OXYGEN MUSCLE SATURATION OF SEMI-PROFESSIONAL SOCCER PLAYERS FOLLOWING A REPEATED SPRINT TEST

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Abstract Dietary nitrates have hemodynamic and metabolic effects on the body. This study aimed to investigate nitrate intake's effect on quadricep muscle oxygen saturation (StO2) of semi-professional soccer players during a repeated speed test (RSA). In a randomized, crossover design, 10 semi-professional soccer men players (21.3 ±0.9yrs) performed two conditions: In one they consumed a nitrate-rich concentrated beetroot juice (250 mL/150 mg of NO3−) and in the other a placebo, 2h before a repeated sprint test. StO2 of the right vastus lateralis muscle was measured by near-infrared spectroscopy. A paired samples t-test was used to compute any differences in the subjects' performance on the StO2 and on RSA test. The level of significance was set at $p < 0.05$. The supplementation of nitrates limited the decrease in muscle oxygenation during the six sprints of RSA test ($p < 0.001$) and also, there seemed to be a tendency for limited the decrement of performance on RSA test ($t = –1.586$, $p = 0.157$, $\eta 2 = 0.218$). In conclusion, acute nitrate supplementation reduces the decrement of muscle oxygenation during exercise with repeated sprints and leads to a tendency of fatigue resistance during repeated sprints under controlled situations. Nitrate supplementation may have an ergogenic effect during exercise with repeated sprints via the higher muscle oxygenation.

Key words: nitrates, repeated sprint ability, NIRS, muscle oxygenation

Introduction

Soccer is an intermittent sport where both aerobic and anaerobic ability are important performance factors. Particularly important is the ability for repeated sprints in a short period of time (Glaister, 2005). This ability depends on neuromuscular as well as metabolic factors (Mendez-Villanueva et al., 2007), while the availability of O_2 seems to play an important role (Smith & Billaut, 2010).

Professional soccer players use a variety of dietary supplements to enhance performance. However, only some of them exhibit ergogenic activity (Burgess et al., 2006) like nitrates. In the last decade several studies have focused on the ergogenic action of nitrates (Jonvik et al., 2018). Nitrates in the human body are converted into nitric oxide (NO) which has hemodynamic and metabolic effects on the body. It is reported that they can cause vasodilation by lowering blood pressure and increasing the transfer of gases and nutrients to the exercised muscles (Jones et al., 2012). In the literature there are studies that report the ergogenic effect of nitrates (Domínguez et al.,

2018; Jonvik et al., 2018; Karampelas et al., 2021) but also others who did not mention any influence (Jonvik et al., 2021; Pawlak-Chaouch et al., 2019; Poredos et al., 2022).

As mentioned above, the ability to repeat sprints is particularly important in soccer. During intense exercise the oxygen consumed by muscles exceeds oxygen supply and the oxygenation level in muscle decreased (Bhambhani, 2004; Grassi et al. 1999). Soon after the end of the exercise, the oxygen supply in muscles exceeds oxygen consumption and the muscle oxygenation level is recovered (McCully & Hamaoka, 2000). However, the time that is needed for reoxygenation after exercises depends on the ratio between oxygen supply and oxygen consumption by muscles. Nitrates during repeated sprints could enhance the transport of gases (like O_2) to the exercised muscles thus helping metabolic pathways like phosphocreatine resynthesis (PCr) (Burgess et al., 2006) enhancing the player's performance. Recent studies show positive effects of nitrates on repeated sprint test performance (Karampelas et al., 2021; Rojas-Valverde et al., 2021; Wylie et al., 2016)

Near-infrared spectroscopy (NIRS) is a non-invasive method used in examining muscle oxygenation which reflects the balance of O_2 delivery to working muscles and muscle O_2 consumption in capillary beds (Hamaoka et al., 1996). The NIRS is based on the differential absorption properties of the heme group of hemoglobins in the vascular bed and the heme group of myoglobin in muscle fibers (McCully & Hamaoka, 2000).

The effect of nitrates on muscle oxygenation during running exercise with repeated sprints has not been investigated. In the literature there are studies that report a change in muscle oxygenation without however a positive effect on the performance of endurance athletes. The aim of this study was to investigate the effect of nitrate intake on quadricep muscle oxygen saturation (StO_2) of semi-professional soccer players during a repeated speed test.

Material and Methods

Subjects

Some of the measurements in this study are part of a larger study (Karampelas et al., 2021). Ten healthy semi-professional male soccer players took part in the study voluntarily (age: 21.3 ±0.9 yrs, weight: 73.49 ±4.44 kg, body fat %: 12.68 ±3.09). The study was approved by the Ethics Committee of the School of Physical Education and Sport Science at Thessaloniki (66/2021) and conformed to the spirit of the Helsinki Declaration. All of the participants were members of soccer teams, trained five days a week and participated in one match a week. The participants were informed about the details of the study and signed the corresponding written consent form. In addition, they completed questionnaires about medical history and nitrate consumption (Karampelas et al., 2021).

Design

Participants participated in two conditions that were at least five days away from each other. In a randomized crossover design, subjects were then assigned to receive placebo (PG) or nitrate (NG) (250 mL/150 mg of NO_3^-). The juice was prepared in the laboratory by mixing beetroot powder with juice.

Each day of measurement was preceded by two days of wash-out. On these days, participants were given a list of foods and beverages that they should not consume as they contain nitrates and may have influenced the study. Participants were asked to record their diet on these days in detail which was checked not to include the above foods. During the participants' first visit anthropometric and height, weight and body fat measurements were made. The design of the study is presented in Figure 1. After a standard warm-up lasting 15 min, the repeated

sprint test (RSA) was carried out (Rampinini et al., 2007). The measurements were made on an open soccer field with synthetic turf. The measurements were carried out in the morning and the only meal that preceded it was in the morning which included food without nitrates. The study was carried out during the season by modifying the contents of the participants' training sessions.

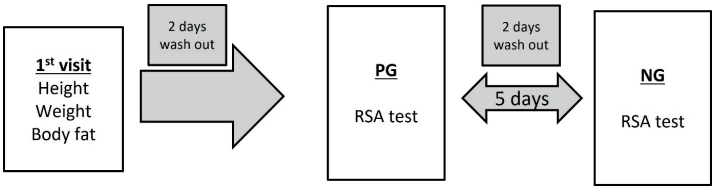

Figure 1. Study design.

Anthropometric Measurements

The following procedure for measuring anthropometric characteristics is described as performed in the study by Karampelas et al. (2021). An electronic digital weight scale and a height scale (Seca 2020e, Seca, Hamburg, Germany) were used to measure the body mass and height of the players. These two measurements had an accuracy of 0.1 kg and 0.1 cm in the respective evaluations. The participants, during the measurements, were barefoot and wearing only underwear. To assess body fat, a Lafayette skinfold caliber (Sagamore, Lafayette, Ins. Co., Indiana) was used to measure the thickness of the soccer players' hypodermic fat in four of their skinfolds (biceps, triceps, suprailiac, subscapular). All skinfold measurements were taken on the right side of the body, and body fat percentage was calculated with the use of Siri equation (1956).

RSA Test (Repeated Sprint Ability Test)

The RSA test consists of 6 × 40 m sprints (20 + 20 m) with a 20 s break in between sprints (Rampinini et al., 2007). The athletes started from the starting line sprinting for 20 m, stepping on a line and returning to the starting point as quickly as possible. They followed with 20 s of recovery before starting the next sprint. In the last 5 s of the recovery time there was a countdown to the athlete being ready to start at the end of the 20 s. In the starting line there were photoelectric gates (photocells) (Microgate, Bolzano, Italy) to record the time of each sprint. Photocells were placed 0.6m above the ground (approximately at the hip level) to capture the movement of the trunk rather than a false signal due to a limb motion. The coefficient of variation for test–retest trials was 4.1%. Three indicators were used from the test: a) RSAbest: the fastest sprint of six, b) RSAmean: the average time of six sprints and c) RSAdec: the rate of decline in performance during the six sprints (was used the time in the fastest sprint and the slowest).

Near-Infrared Spectroscopy

Moxy (Fortiori Design LLC, Hutchinson, MN, USA) a portable NIRS apparatus was used in this study. Moxy is a compact (61 × 44 × 21 mm) and lightweight (48 g) system which employs four wave lengths of NIR light at 680, 720, 760 and 800 nm (Schmitz, 2015). The sensor contains a single LED and two detectors were placed 12.5 and 25.0 mm from the source. Moxy measures the ratio of the oxyhaemoglobin concentration in the muscle in real

time and reports it as a percentage, which is indicated as muscle oxygen saturation (StO_2) or muscle oxygenation (SmO_2). Data acquisition (2Hz) was obtained from the internal memory sensors and extracted from the device as a csv file. The CV values for Moxy when resting were 5.7% to 6.2% (McManus et al., 2018). Moxy was positioned on the right vastus lateralis muscle belly (approximately 10–12 cm above the patella) before exercise using a black plastic spacer. The probe was held in place via double sided, stick discs and black bandages to reduce the intrusion of extraneous light (Michailidis et al., 2020).

Statistical Analysis

Descriptive statistics (mean ± standard deviation, SD) were calculated for each parameter. Data normality was verified with the Kolmogorov–Smirnoff test. A paired samples t-test was used to compute any differences in the subjects' performance on the muscle saturation and on RSA test. The level of significance was set at $p < 0.05$. Effect sizes (ES) were estimated by calculating partial eta squared $\eta^2 = t^2 / (t^2 + N\text{-}1)$ and were classified as small (0.01 to 0.058), medium (0.059 to 0.137) or large (0.138 or higher) according to Cohen (1988). The SPSS version 25.0 was used for all analyses (SPSS Inc., Chicago, IL, USA).

Results

In Figure 2 the typical kinetic of oxygen saturation during RSA test for the two conditions (PG & NG) is presented. It is obvious that the supplement of nitrates limited the decrease in muscle oxygenation during repeated sprints.

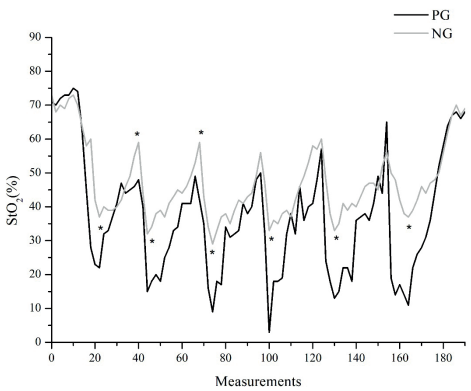

Figure 2. Typical kinetic of oxygen saturation during RSA test for the two conditions (NG & PG). * Denotes significant difference between the conditions

In Table 1 the baseline values, the lowest value after each sprint and the maximum value of muscle oxygenation during recovery of each sprint as well as the statistical indicators are presented.

Table 1. The lowest values of StO2 after each of the six sprint, the max values of StO2 during recovery after each of the six sprint and statistical indicators (mean ± standard deviation, SD)

Measurement	NG	PG	t	p
Pre	73 ±10	71 ±12	1.296	0.114
Lowest after 1st sprint	39 ±12	22 ±15	6.547	<0.001
Recovery after 1st sprint	59 ±16	48 ±18	5.810	<0.001
Lowest after 2nd sprint	32 ±14	15 ±16	16.588	<0.001
Recovery after 2nd sprint	59 ±18	49 ±19	5.361	<0.001
Lowest after 3rd sprint	29 ±17	9 ±20	42.458	<0.001
Recovery after 3rd sprint	48 ±18	50 ±17	1.686	0.063
Lowest after 4th sprint	33 ±18	3 ±25	15.595	<0.001
Recovery after 4th sprint	60 ±16	57 ±18	1.885	0.086
Lowest after 5th sprint	33 ±18	13 ±16	23.066	<0.001
Recovery after 5th sprint	56 ±20	65 ±19	1.745	0.112
Lowest after 6th sprint	38 ±17	11 ±16	23.209	<0.001
Recovery after 6th sprint	69 ±18	55 ±17	1.325	0.418

The results of the statistics for the RSA test did not show any significant differences between the two conditions for each indicator of the test: RSAbest ($t = 1.382$, $p = 0.210$, $\eta^2 = 0.175$), RSAmean ($t = –0.339$, $p = 0.745$, $\eta^2 = 0.013$), RSAdec ($t = –1.586$, $p = 0.157$, $\eta^2 = 0.218$).

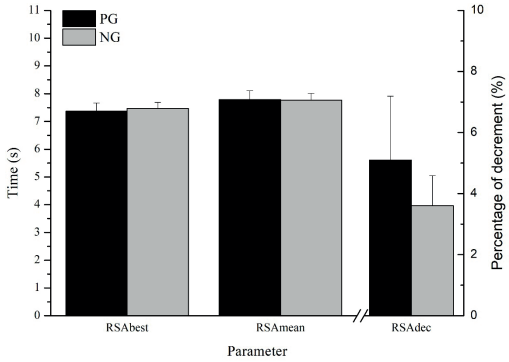

Figure 3. RSA best sprint; RSA mean time; RSA percentage of performance decrement

Discussion

The results showed that nitrate supplementation can affect the StO_2 of the muscles during exercise. However, this effect did not improve the performance of the players in the RSA test. We have to mention that in RSAdec there seemed to be a tendency for limited the decrement of performance, but this was not statistically significant.

Indications from the bibliography for the possible ergogenic activity of nitrates led the International Olympic Committee (IOC) classify them as a dietary supplement that can improve performance (Mowbray et al., 2009). Nitrates in the human body are converted into nitric oxide (NO) (Maréchal & Gailly, 1999) which is important for several signaling pathways of the body related to exercise, such as vasodilation, mitochondrial respiration, blood flow and muscle contraction (Arazi & Eghbali, 2021; Haider & Folland, 2014). More specifically, NO increases blood flow

during exercise (Menard et al., 2008) which is considered to improve athletic performance as the muscles are supplied with O_2 and glucose (Bailey et al., 2010) and may help re-synthesize phosphocreatine (PCr) between the sets (Trump et al., 1996; Vanhatalo et al., 2011). In addition, better blood flow accelerates the removal and metabolism of lactic acid which can be a limiting factor in performance in exercise with repeated sprints. It is also mentioned that nitrates reduce the cost of high-energy phosphates in the generation of skeletal muscle contraction (Bailey et al., 2010; Fulford et al., 2013) and the intramuscular accumulation of adenosine diphosphate (ADP) and phosphate, factors that are expected to reduce the expansion of fatigue in skeletal muscle (Allen et al., 2008).

Nitrate supplementation did not affect any of the RSAmean, RSAbest and RSAdec indicators. However, in the NG condition the decrement in performance was more limited. This observation may be based on the fact that nitrates can limit the required energy to produce ATP and the use of phosphocreatine (Larsen et al., 2007).

It was recently reported that in order to have a positive effect on performance, the nitrate supplement should be >5 mmol/serving (Gallardo & Coggan, 2019; Peeling et al., 2015). A recent review article states that there are differences between acute and chronic supplementations (Rojas-Valverde et al., 2020). The authors state that chronic administration should be given 2 times a day in concentrations of ~5–6.5 mmol of NO3 (70 ml in the morning and 70 ml in the evening) (Kent et al. 2019; Reynolds et al. 2020). On the other hand, acute intake should be given 2–3 hours before exercise with 70 ml of a concentration of ~5-6.5 mmol of NO3 (Kokkinoplitis & Chester 2014; Thompson et al. 2015). A dose above the 5 mmol/l threshold was used in the present study, however no significant effect on performance was observed

This is the first study to investigate the effect of nitrate supplementation on the muscle saturation StO_2 of vastus lateralis in semi-professional soccer players during a repeated sprint ability test. Bailey et al., (2009) showed that deoxyhemoglobin peak amplitude was significantly smaller after nitrate supplementation for 4–6 days. In contrast, in a more recent study no differences were shown in StO_2 with nitrate supplementation during exercise (Husmann et al., 2019) although, the researchers mentioned that a subsample analysis of those who have improved their time to exhaustion with dietary nitrate has revealed a significant condition effect. In another study Haider and Folland (2014) mentioned that nitrate supplementation increased peak force at low frequencies of electrical stimulation (1–20 Hz) and explosive force production at low (1 Hz) and high (300 Hz) frequencies of stimulation during unilateral isometric contractions of the knee extensors in untrained individuals. However, these moderate effects on the contractile properties did not translate into any significant changes in maximum or explosive voluntary force production. In the above studies, nitrates were taken for a period (e.g. 1 week) before the test in contrast to the present study which used a single dose of nitrates before the test.

However, there are also some limitations to the study, such as the small sample used, which does not allow us to generalize the results. The changes in plasma concentrations of nitrates (NO_2 and NO_3) after taking the supplements were also not measured to confirm the effect of supplements.

Conclusions

In conclusion, acute nitrate supplementation reduces the decrement of muscle oxygenation during exercise with repeated sprints and leads to a tendency of a fatigue resistance during repeated sprints under controlled situations. Factors such as dosage and the chronic or immediate intake of supplement can affect their ergogenic effect. Additional studies are needed on the role that high flow of oxygen can play in the exercised muscle for both performance and rehabilitation.

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COMPARISON OF EFFECTIVENESS OF PROLOTHERAPY AND CORRECTIVE EXERCISE PROGRAM VS PROLOTHERAPY AND ISOMETRICS STRENGTHENING ON PAIN AND FUNCTIONAL IMPROVEMENT IN SUPRASPINATUS TENDINOPATHY IN A TERTIARY CARE CENTRE

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Abstract **Background** Regenerative injection therapies such as prolotherapy have gained importance in the recent years in non-surgical management of supraspinatus tendinopathy. The aim of the present study was to compare the efficacy of isometric rotator cuff strengthening versus corrective exercise program in the treatment of supraspinatus tendinopathy. **Material and Methods** Fifty patients aged 18–60 years were recruited with MRI diagnosed isolated supraspinatus tendinopathy or < 50% thickness tear and symptoms persisting for longer than 6 months. All patients were randomised into two groups: one prolotherapy with isometric rotator cuff strengthening exercise therapy (group ISE; n = 25) and the other group also treated with prolotherapy injection followed by corrective exercise program (group CEP; n = 25). Patients were examined at baseline, 3, 6, and 12 weeks. Improvement was assessed using a visual analog scale (VAS) for pain, and Constant Murley Score (CMS) for shoulder function. **Results** Significant difference (p < 0.001) was found between the groups in the VAS and CMS at any follow-up period. **Conclusion**

Prolotherapy with CEP is more beneficial than prolotherapy with isometric strengthening exercise in supraspinatus tendinopathy. Improvement in pain and functional movements is more in the prolotherapy with CEP group than prolotherapy with ISE group.

Key words: supraspinatus tendinopathy, prolotherapy injection, corrective exercise program

Introduction

Tendon overuse injuries (tendinopathies) constitute a major proportion of sports injuries. More than 50% of patients presenting with shoulder pain are diagnosed to be partial thickness supraspinatus tear or supraspinatus tendinosis (Kim et al., 2010). Clinical presentation of tendinopathy includes pain during/after exercise or associated with morning pain after waking up, and increased pain with increased load demonstrated in provocative manoeuvres. (Greis et al., 2015).

Non operative management is the primary treatment of supraspinatus tendinopathy without complete tear which includes rest, activity modification, exercise therapy like rotator cuff strengthening and non-steroidal anti-inflammatory drugs (Serafini et al., 2009). The role of inflammation continues to be a point of controversy for intervention related to tendinopathy. Cook and Purden (2009) investigated a variety of human tendons indicating that there are no inflammatory cells in degenerative tendons whereas another study reported an increase in presence of inflammatory cells in pathological tendons (Andarawis-Puri et al., 2015). It is hence prerogative that corticosteroid and non-corticosteroid medications may carefully be administered for pain relief (Dean et al., 2016), as chronic tendinopathies are mostly degenerative in nature, and as such, corticosteroids may have adverse effects on tendon healing (Gialanella & Prometti, 2011). Regenerative injection therapies like platelet rich plasma (PRP) are under usage, yet their effectiveness is a point to ponder (Sánchez-González et al., 2012). Dr. Hackett, was the first person to use prolotherapy, which is an injection technique (Munk et al., 1998). Prolotherapy has been identified as a regenerative injection therapy which is in line with other regenerative injection therapies such as PRP and other stem cell injections by the absence of a biologic agent (Rabago et al., 2013). Prolotherapy is being used for the treatment of various musculoskeletal conditions such as ligamentous laxity, osteoarthritis and tendinopathies like patellar, Achilles, tennis elbow. (Topol et al., 2016); (Ryan et al., 2011); (Ryan et al., 2010); (Reeves et al., 2016).

Ease of application, and reduced time for rehabilitation are the reasons reported for the preference of prolotherapy, where no serious side effects were reported for prolotherapy when used for the above-mentioned conditions (Rabago and Nourani , 2017). However, the mechanism of action of prolotherapy.is by causing local irritation with subsequent inflammation and tissue healing resulting in enlargement and strengthening of damaged ligaments, tendons and intra-articular structures (Lin et al., 2019). The primary objective of the present study was to assess the improvement in pain intensity and shoulder function in patients with supraspinatus tendinopathy at 3, 6 and 12 weeks as measured by VAS (visual analogue score) and CMS (constant murley score) scores respectively. In multiple clinical trials, hypertonic dextrose is the most commonly used prolotherapy solution (D'Lima, 2016). The proposed mechanism of action is transport of dextrose into human cells by using GLUTs 1–4 transport proteins, and this dextrose interacts with DNA to signal either cell growth or repair, Thereby, DNA expression changes, favouring the production of multiple cytokines (Laiguillon et al., 2015). Hence, prolotherapy could be identified as a useful option to treat the supraspinatus tendinopathy.

There are limited studies in literature comparing the prolotherapy and non-operative management in treatment of supraspinatus tendinopathy. Till date, only few randomised controlled studies were found evaluating the use of prolotherapy in supraspinatus tendinopathy, of which, three studies favoured prolotherapy (Bertrand et al., 2016), (Seven et al., 2017) and (Sari and Eroglu, 2020). One study deferred against prolotherapy (Cole et al., 2018) and one study was inconclusive. (Cook and Lewis, 2019). This apart, exercise therapy is a known line of treatment followed in the management of supraspinatus tendinopathy where mechanical loading of a tendon helps in its repair. Hence, loading a tendon in the form of isometric, concentric, and eccentric exercises should be considered in the rehabilitation program (Maeda et al., 2009). Appropriate loading forces induce a tensile stretch to tenocytes, and activate protein kineases. (Killian et al., 2012). Evidence regarding the efficacy of exercises in adults is substantial where exercises has been advocated to be cost-effective. Exercise regimen in conditions like rotator cuff tendinopathy is an effective modality in terms of pain reduction, improvement in work-ability, and potential improvement for return-to-work when compared to a control intervention or to a placebo. (Desmeules et al., 2016). Considering all these into account, we hypothesised that prolotherapy combined with a corrective exercise program helps in pain reduction and increasing range of movement in patients with supraspinatus tendinopathy. This study compares the efficacy of prolotherapy with isometric strengthening exercises (ISE) versus prolotherapy with corrective exercise program (CEP) in the treatment of supraspinatus tendinopathy.

Material and Methods

This was a randomised controlled study conducted in Department of Sports Medicine and Sports Sciences (SISSM), Saveetha Medical College, Chennai, India. Ethical approval was taken prior to start of the study.

Sample size calculation

In a study by Seven et al (2017), the observed mean value of VAS at 12 weeks after prolotherapy for chronic rotator cuff lesions was 2.35 ±1.98 and in control group was 4.00 ±2.11, taking these values as reference, the minimum required sample size with 80% power of study and 5% level of significance was 24 patients in each study group. So, total sample size taken was 50 (25 patients per group).

Inclusion and exclusion criteria

Patient selection was based on the following inclusion criteria: age of the patients above 18 years, pain in the shoulder of more than 6 months duration, with evidence of isolated supraspinatus tendinopathy in MRI (tendinosis or <50% thickness tears) with persistent pain despite conservative treatment given for more than 2 months, and consenting to be a part of this study. Exclusion criteria were the presence of any of the following: (i) patients with >50% thickness tears of the supraspinatus tendon on MRI (ii) associated tendinopathy of other rotator cuff muscles (iii) systemic inflammatory arthritis, including ankylosing spondylitis, rheumatoid arthritis or psoriatic arthritis (iv) patients with prior rotator cuff tear (v) history of diabetes mellitus or hypertension (vi) patients with infection, known malignancy, bleeding disorder or pregnant patients, and (viii) patients who had received previous corticosteroid injection or PRP injection in the same shoulder.

Totally 14 patients were excluded among the 64 patients. In those, 9 patients were involved with other rotator cuff muscles and 5 patients already received PRP injection previously in the same shoulder.

Randomisation and groups

After enrolment, the patients were randomly divided into ISE and CEP groups by using bowl method without replacement technique. The patient had to pick a card from the bowl containing 1 to 50 numbers (25 odd & 25 even numbers). The picked card was not replaced to ensure equal numbers in both groups. Both groups received the same dose of prolotherapy injection. Group ISE received prolotherapy (25% dextrose) injection followed by isometric rotator cuff strengthening exercises given, whereas Group CEP also received the prolotherapy (with 25% dextrose) followed by the corrective exercise program (Table 1) given.

Procedure for prolotherapy injection

In sitting position, the affected shoulder was disinfected under strict aseptic precautions using 1% povidine iodine and spirit. By palpating posterior joint line of the shoulder, soft spot was identified 1 cm below and lateral to the acromian process. Using a 27G needle, 5–7 ml of prolotherapy solution (25% dextrose) and 1–2 ml of lidocaine (local anaesthetic) was injected in the subacromial space by the sports medicine physician. Post injection, icepack was used for pain control. Only paracetamol tablets (maximum 3 tablets a day) of 500 mg strength were allowed to the patient as rescue analgesic after injection for a maximum period of 10 days on need basis.

Rehabilitation protocol

After prolotherapy, group ISE advised for isometric rotator cuff strengthening, 12 repetitions* 3 sets with holding duration of 8–10 seconds for each repetitions. In group CEP, corrective exercise program by Lindell. C., 2017 was advised (Table 1). Force couples occur when the resultant force of two opposing muscle groups achieves a given moment. The rotator cuff acts as a force couple around the joint, with co-activation of agonist and antagonist muscles, as well as coordinated activation of the agonist and inhibition of the antagonist muscle (Lugo et al., 2008). This helps in producing the torques and accelerations necessary for using the glenohumeral joint. Deltoid, rotator cuff and upper trapezius-serratus anterior acts as force couples (Cools et al., 2014).

Table 1. Corrective Exercise Program

S No	Exercise	Reps	Sets
1	90/90 scapular stabilization in prone position	12	3
2	Overhead carries (kettlebell)	12	3
3	Sidelying external rotation with dumbbell	12	3
4	Bosu ball push ups	12	3
5	Dynamic scapular stability drill with slider	12	3

Follow up and outcome measures

The patients were assessed at the time of enrolment, and at 3, 6 and 12 weeks follow up to assess the level of pain and functional status. The patients were asked to rate their pain on VAS - a subjective scale where 0 indicates no pain and 10 indicates worst possible pain. To measure the functional outcomes, CMS was used. It ranges from 0-100. It has 4 components. 1. pain (15 pts), 2. activities of daily living (20 pts), 3. strength (25 pts), 4. range of motion (40 pts). Score of <30 = unsatisfactory, 30–39 = fair, 40–59 = good, 60–69 = very good and >70 = excellent.

Statistical analysis

Categorical variables were presented in number and percentage (%) and continuous variables were presented as mean ±SD and median. Normality of data was tested by Kolmoglorov-Smirnov test. Quantitative variables were compared using unpaired t-test for normally distributed or Man Whitney test for non-normally distributed data and qualitative variables were compared using Chi- square test. A *P* value of <0.05 was considered statistically significant.

Results

CEP Group participants had pain and shoulder improvement, as described by VAS and CMS scores in as compared with ISE Group. Baseline characteristics for the two are given in the Table 2. No significant difference was found in the baseline characteristics between the study groups mentioned in the Table 2.

Table 2. Baseline characteristics

	ISE Group	CEP Group	P value
Age	34.7 ±10.0	34.6 ±10.3	0.9
Sex (males:females)	16:9	19:6	1.0
Laterality (right:left)	17:8	17:8	0.4
VAS-day 0	7.0 ±1.2	6.7 ±1.2	0.4
Constant score-day 0	69 ±8.3	68.4 ±8.5	0.7

Pain intensity for both groups measured at 3, 6 and 12 weeks after intervention. In the within-group comparisons, ISE group as well as CEP group achieved a significant improvement in the VAS scores at 3, 6 and 12 weeks (P = <0.05), when compared to baseline values, except for the CMS score at 3 weeks, for which the P value for comparison to baseline value was 0.06 (Tables 3 and 4, Figures 2 and 3). The baseline value of VAS in the ISE group was 6.7 ±1.2, which improved to 3.4 ±1.3 at 12 weeks (Table 3). The baseline value of VAS in the CEP group was 7.3 ±1.2 which improved to 4.0 ±1.2 at 12 weeks. Similarly, the baseline and 12 weeks value of Constant score in the ISE group were 68.3 ±8.5 and 84 ±5.8 respectively, and in the CEP group were 69.0 ±8.2 and 82.3 ±7.1 respectively (P < 0.05).

Table 3. VAS at each follow-up

	IES Group		**CEP Group B**		
	Mean ±SD	**P value for comparing to day 0**	**Mean ±SD**	**P value for comparing to day 0**	**P value for comparison of group A vs group B**
Day 0	7.4 ±1.3		6.7 ±1.2		0.4
3 weeks	5.6 ±1.0	<0.01*	5.6 ±1.1	<0.01*	0.4
6 weeks	4.9 ±1.1	<0.01*	4.8 ±1.0	<0.01*	0.9
12 weeks	4.0 ±1.2	<0.01*	3.4 ±1.3	<0.01*	0.2

VAS- visual analog scale

* Statistically significant *P* value, with significance set at 0.05; SD- standard deviation.

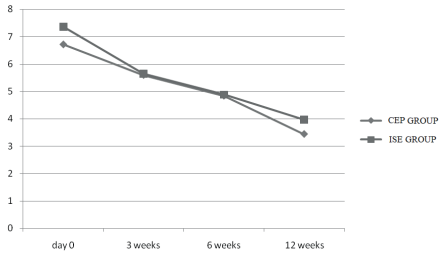

Figure 1. VAS score at each follow up

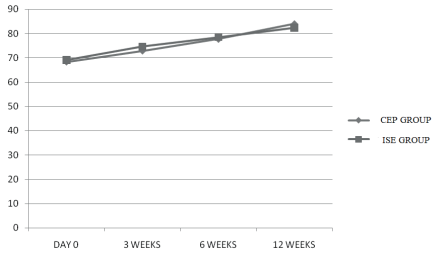

Figure 2. CMS score at each follow up

In the between group comparison, there was no significant difference between the ISE group and CEP group in the VAS and CMS. (Tables 3 and 4). The numerical values and the improvement in (Figures 1 and 2) suggest the benefits of CEP with prolotherapy is more than the isometric with prolotherapy group. None of the patients experienced any serious complications like bleeding, cellulitis or infection. Only 4 patients experienced moderate pain which was managed by paracetamol on need basis and local application of ice packs.

Table 4. CMS score at each follow-up for prolotherapy and corrective exercise program

	ISE Group		CEP Group		
	Mean ±SD	P value for Comparing to day 0	Mean ±SD	P value for comparing to day 0	P value for comparison Of group A vs group B
DAY 0	69.0 ±8.3		68.4 ±8.5		0.7
3 WEEKS	74.6 ±7.8	0.019*	73.0 ±8.3	0.061	0.5
6 WEEKS	78.5 ±7.1	0.00*	77.8 ±6.5	0.00*	0.7
12 WEEKS	82.4 ±7.1	0.00*	84.0 ±5.8	0.00*	0.1

* Statistically significant *P* value, with significance set at 0.05; SD – standard deviation

Discussion

In the present study, prolotherapy with corrective exercise program (CEP) showed improvement in pain (VAS) and function (CMS) at 3, 6 and 12 weeks as compared to baseline in the management of supraspinatus tendinopathy (SST).

Although there was no statistical significance, prolotherapy with addition of CEP has clinical significance in terms of pain score and functional score.

Cole et al (2018). compared prolotherapy with the corticosteroid and concluded that prolotherapy offered no additional benefit in supraspinatus tendinopathy). However, some authors reported significant improvements with prolotherapy as well. Lin et al. (2018) found improvement in shoulder pain (VAS) and shoulder function (SPADI) as compared to a placebo group. One study reported improvement in pain with prolotherapy in patients with painful rotator cuff tendinopathy, after 9 months of follow up, compared with blinded saline injection (Bertrand et al., 2016). Similarly, Lee et al (2015), in a retrospective comparison, showed significant improvement in VAS, SPADI and AROM with prolotherapy, and thus showed improvement in pain and disability, improvement in isometric strength of shoulder, and AROM of shoulder.

Our study identified prolotherapy as a useful injection technique because it is relatively safer as compared to the complications of local corticosteroid injections, where Nicholas et al. (2005) reported such as tendon rupture/ weakening, subcutaneous fat atrophy, and skin hypopigmentation as the few common complications following corticosteroid injection.

Similarly, minor complications like pain, light headedness, allergy or infection were reported for prolotherapy in the literature. Dorman (1993) found a very low complication rate was found for prolotherapy with only 6 out of 272 subjects reporting any complications.

Further, the complication was restricted to only transient increase in pain for 1-2 days. (Catapano et al., 2020). In the present study, we did not observe any complication other than pain in 4 out of 25 patients (16%). The pain was managed by need based paracetamol and application of ice packs.

Further, studies have explored the effect of isometric exercises in the treatment of tendinopathy, in particular, its acute analgesic role. Exercise regimens, referred to as tendon loading programs, remain the most effective conservative approach in the treatment of tendinopathy where tendon loading exercises have shown beneficial effects in patients with chronic achilles tendinopathy and patellar tendinopathy (Millar et al., 2021).

Supraspinatus tendinopathy has shown greater improvement with a progressive loading program, rather than complete rest, with other treatment modalities used as adjuncts mainly targeted at achieving pain relief (Cardoso et al., 2019).

In the present study, prolotherapy with isometric rotator cuff strengthening exercise (group ISE) was compared with prolotherapy plus corrective exercise program (group CEP). Group B participants in our study underwent prolotherapy followed by a corrective exercise program consisting of selective muscle activation of the force couples [90/90 scapular stabilization, overhead carries, side lying dumbbell-external rotation] followed by the plyometrics (Lindell, 2017), we found that the combination of prolotherapy along with the CEP is beneficial on the supraspinatus tendinopathy.

The duration of follow up for our study was 3 months, which we felt was sufficient. However, for the condition under consideration, treatment is expected to result in improvements within this period and longer follow up may lead to better assessment of results. The age of the participants (18 to 60 years) in this study could have played a significant role in the result of this study, as it is possible that the efficacy of prolotherapy injection may produce different results in different age groups in rotator cuff tendinopathy. Similarly, sample size was not large enough to permit any subgroup analysis based on age, pain and other characteristics. It is however possible that inclusion

of a pain-relieving modality and with a larger sample size could lead to more prominent subgroup analysis in the near future. Further research might enlighten the accurate benefits of such combination of techniques.

Conclusion

Regenerative injection techniques such as prolotherapy is found beneficial for pain management in supraspinatus tendinopathy. Prolotherapy combined with a corrective exercise program showed better pain reduction and increased range of movement. Moreover, combining prolotherapy with a corrective exercise program enhanced the overall functional independence of the participants. However, a long-term follow-up may show further benefits of such techniques towards pain and range of movement.

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THE IMPORTANCE OF PERSONALITY TRAITS, OPTIMISM AND QUALITY OF LIFE FOR PAIN THRESHOLD AND PAIN TOLERANCE IN THE ELDERLY

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Abstract With increasing age, the frequency of chronic pain increases compared to acute pain. This is due to structural and functional changes caused by ageing of the nervous system. The aim of this study was to investigate relationships between personality traits, optimism, quality of life, and subjective assessment of pain measured experimentally with an algometer and clinically with the Visual Analoque Scale (VAS). In the group of 133 seniors (61–86 years; 78% women), we used an algometer to measure pain threshold and tolerance, the VAS scale to assess subjective intensity, and standardized questionnaires (EPQ-R(s), LOTR, SWLS) to measure psychological variables. Extraversion was found to promote both higher pain threshold and higher pain tolerance, whereas pain tolerance was negatively correlated with neuroticism. Higher severity of the psychotic trait was associated with more intense subjective pain experience. Optimism and overall quality of life were not associated with any pain measures. A better understanding of the personality correlates of pain perception could support a more accurate tailoring of pain management in elderly patients.

Key words: pain perception, algometer, Visual Analoque Scale, elderly, personality traits, optimism, quality of life

Introduction

Scientific studies have shown that people's response to pain and their sensitivity to positive and negative stimuli are very different (Price, 2000). According to the International Association for the Study of Pain (IASP), pain is described as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of such damage" (Raja et.al., 2020). Physiologically, pain has an informational and warning function in that it indicates impending or threatened tissue damage. Its protective function, in turn, greatly increases a person's chances of survival by allowing them to recognize their environment and avoid situations that could threaten their health or life (Pawlak et al., 2019). Pain or its absence is also a subjective criterion for illness or health. A complex combination between personality and its effect on pain perception is observed (Pawlak, 2013). It is known that pain perception is highly modulated by the circumstances in which it occurs. Environmental, social, and also emotional or religious factors play a special role in the perception of pain stimuli (Gatchel et al., 2007). Psychological factors, including personality, have also been shown to determine individual differences in pain threshold and pain tolerance, as well as how we cope with pain (Seminowicz & Davis, 2006; Lim et al., 1983). Thus, pain perception can be enhanced or attenuated depending on a person's motivation, activity, life satisfaction, or stress coping strategy.

Personality traits have a significant impact on the patient's perception of pain and attitude (Levine et al, 1966; Lynn & Eysenck, 1961). According to Eysenck, extroverts and psychopaths have a higher pain tolerance than introverts, due to a more rapid increase in cortical inhibition and the resulting tendency to suppress sensory stimuli (Eysenck, 1967). Extroverts are open-minded and curious about the outside world; their lives are empirically richer. They are willing to embrace innovative ideas and unconventional values. Compared to closed-minded people, they are more willing to experience both positive and negative emotions. They willingly enter into new social relationships and face the situations they encounter in life with optimism. Psychopaths, on the other hand, are antisocial, aggressive, often insensitive and extravagant people (Eysenck, 1970). High levels of psychoticism often lead to various mental disorders, such as psychosis. According to Lynn and Eysenck, the final dimension of personality is neuroticism, which is defined as the highest level of emotional instability (Lynn & Eyseneck, 1961). Neurotic people are more prone to exaggeration and have difficulty returning to a normal level of emotional activity. Some cognitive and behavioral traits have also been shown to be significantly related to pain (Goubert et al. 2004; Kadimpati et al., 2015). Research shows that catastrophism influences the relationship between negative affect (neuroticism), pain, and functional disability (Vervoort et al., 2006; Swinkels-Meewisse et al., 2006). People who tend to have catastrophic thoughts about their pain very often get into a so-called vicious cycle of fear of pain, increased vigilance, and avoidance, which in turn increases pain. It seems that optimism can protect against the development of this vicious circle and prevent the occurrence of chronic pain. Optimism as a personality trait generally means optimistic expectations and a tendency toward positive feelings and satisfaction with life (Scheier & Carver,1987). Many studies have shown that optimists respond more positively to health-threatening situations (Carr, 2009), do not catastrophize, and do not show excessive vigilance to negative information. In experimental studies of pain, optimists are aware that the harmful effects of the stimulus are temporary and will soon pass.

In turn, the studies by Geers et al. (2008) showed that optimists are not more resistant to pain stimuli (Geers et al., 2008). The authors explain that compared to pessimists, optimists are more flexible in dealing with pain because they focus their attention on the positive aspects of the situation and use active pain management strategies (Ramirez-Maestre et al., 2012; Saariaho et.al., 2010).

Over the past 30 years, there has been a significant increase in interest in describing and measuring the quality of life of older people (Fayers & Machin, 2007).

The concept of life satisfaction is semantically related to such terms as: well-being, satisfaction and quality of life. Mostly, health-related quality of life is measured by the aspects of overall quality of life that can be clearly shown to affect physical and mental health (Diener et al., 1985).

Many studies suggest that the quality of life of older people depends more on personality traits and social situation than on the biological state of the body (Felce & Perry, 1995).

From published research it appears that people strive for life satisfaction and are generally satisfied with it (Diener & Diener,1996). The occurrence of the disease is associated with lower life satisfaction compared to healthy people (Hyphantis et al., 2013; Czapiński, 2008).

In healthy people, life satisfaction is related to extraversion and negative emotionality, whereas in patients, social inhibition and conscientiousness are predictors of satisfaction. This proves that the satisfaction level of healthy people results from their own activity and contacts with other people, while in sick people the fulfilment of social and professional roles plays an important role in the satisfaction level (Kozaka & Kobus, 2015).

In aging, cognitive, emotional, and social pain competencies have both direct and indirect effects on pain perception. Many authors point out that the mental and physical health of older people has a significant impact on their quality of life and their perception of pain (Schoenborn et al., 2013; McAuley et al., 2003).

The aim of this study was therefore to investigate the relationship between personality traits, optimism and quality of life, and subjective assessment of pain measured experimentally with an algometer and clinically with the Visual Analoque Scale (VAS).

Materials and methods

Participans

Study sample consisted of 133 seniors (77.4% woman), aged 61–86 years, mostly with secondary or higher level of education, differentiated by places of residence.

Pain Measurement

PPT, PTOL. Tissue pressure sensitivity measurements were performed using an FPN 100 Algometer (Wagner Instruments, Greenwich, USA) with a measurement range of 0 to 20 kg and an attached disk-shaped rubber tip of 1 cm^2. Measurements were taken on the dominant upper limb, on the dorsum of the hand between the thumb and index finger.

Two tests were performed with this device to determine pain threshold (PPT) and pressure pain tolerance (PTOL). PPT is defined as the minimum pressure required for the sensation of pressure to first change to pain, whereas PTOL describes the maximum stimulus intensity or duration of continuous painful stimulation that a subject is willing to endure.

All participants were instructed on how to use the algometer and then allowed to use the device. They were tested in a sitting position, and measurements were taken on the dominant upper extremity on the dorsum of the hand between the thumb and index finger. All measurements were taken by the same researcher. When pain occurred, the participant said ‘stop,’ and this measurement was used as an indicator of pain threshold (PPT result). The measurement was then continued until the participant could no longer tolerate the stimulus and signaled the

end of the measurement. The point at which a painful pressure stimulus could no longer be tolerated was used as the pain tolerance measurement (PTOL result).

Visual Analog Scale (VAS)

After completing PPT and PTOL tests, the patients were asked to indicate their subjective pain level using the Visual Analog Scale (VAS) to assess the degree of subjective pain experienced during the procedure compared to an individual subjective amount of pain experienced in life. The pain intensity was assessed using a scale from 0 = "No pain and discomfort" to 10 = "The worst possible pain and discomfort".

Psychological traits

Personality

Eysenck EPQ-R Personality Questionnaire.

The questionnaire aims to examine the basic dimensions of personality contained in Eysenck's theory (Eysenck & Eysenck, 1994). It allows an initial determination of personality in the following dimensions: Extraversion, Neuroticism, Psychoticism and Tendency to present oneself in a good light. Higher scores on the Neuroticism scale (EPQ-N) indicate an anxious, fearful, overly emotional, and somewhat rigid personality. A higher score on the Extraversion Scale (EPQ-E) indicates an outgoing, optimistic, exciting, and relaxed personality. Higher scores on the Psychoticism Scale (EPQ-P) indicate an uninhibited, hostile, and maladjusted personality, and Lying (EPQ-L) represents uncomplicated hypocrisy (Jaworowska, 2011).

Optimism

Optimism was measured with the Life-Orientation Test- Revised (LOT-R), a 10-item measure of optimism versus pessimism created by Scheier and Carver (1985) in Polish adaptation by Poprawa and Juczynski (Scheier & Carver, 1987). Of the 10 items, six of them measure optimism (e.g., *In uncertain times, I usually expect the best,* and *If something can go wrong for me, it will*, reverse-scored), and four items serve as fillers. Respondents rated each item on a 5-point scale from 0 = strongly disagree to 4 = strongly agree.

Quality of life

The Satisfaction with Life Scale (SWLS) is one of the most widely used tools to measure the cognitive dimension of subjective well-being (Kjell & Diener, 2021; Juczyński, 2001). The SWLS contains 5 statements. The range of its results is in the range from 5 to 35 points, and a higher score means a sense of greater satisfaction with life.

Study design

The study involved seniors attending courses in senior citizens' clubs and at the University of the Third Age in Szczecin and Gdansk. Subjects were informed of the purpose of the experiment and the possibility of dropping out at any time. The Bioethics Committee of the Regional Medical Chamber in Gdansk approved the study (KB -10/19).

After written informed consent to participate in the study, pain threshold and pain tolerance tests were performed, as well as assessment of subjective pain perception using the VAS scale. Participants were then asked to complete a demographic survey and research questionnaires. Seniors completed the questionnaires without assistance but in the presence of the researcher. If the participant had difficulty completing the questionnaire, they could ask the researcher for help, but in any case, all answers were exclusively their own.

Results

In subjective pain assessment using an algometer, analyzed seniors achieved threshold scores from 0.1 to 4.1, while pain tolerance was scored from 0.8 to 20.3. In the assessment of subjective pain intensity participants scored the maximum possible range from 1 to 10. Table 1 contains basic sociodemographic and pain measurements results, described by mean (*M*) and standard deviation (*SD*) for quantitative variables and frequency (*n*) and percentage (%) for qualitative ones.

Table 1. Sociodemographic characteristics and pain measurements results in study sample

Variables	*N/M*	*%/SD*
Age in years	72.68	5.57
Gender		
woman	103	78.0
man	30	22.0
Education		
primary	3	2.3
vocational	20	15.0
secondary	58	43.6
higher	44	33.1
higher and more	8	6.0
Place of residence		
village	24	18,0
small town	36	27.1
medium town	44	33.1
cities	27	20.3
big cities	2	1.5
Pain threshold (algometer)	1.15	1.26
Pain tolerance (algometer)	5.53	3.05
Pain intensity (VAS)	6.57	1.80

Table 2 presents the results of the Spearman's correlation analysis between pain measurements (threshold, tolerance and subjective intensity) and psychological factors as personality features, optimism and general quality of life. Three personality dispositions turned out to be significantly correlated with objective and subjective pain measurements. Extraversion was positively associated with pain tolerance (rho = 0.217; p = 0.012) and threshold (rho = 0.198; p = 0.023), which suggests that among analyzed seniors increased social openness coexisted with higher pain resistance. More introverted seniors were found to be slightly more sensitive to physical pain. Only pain tolerance negatively correlated with the neurotic domain of personality (rho = –0.180; p = 0.038). This result indicates that higher emotional stability can promote better pain tolerance – more negative affect coexisted with increased pain intolerance. Differently to extraversion, neuroticism was not related to pain threshold (p > 0,05). Psychoticism was the last personality disposition significantly associated with pain experiences – but only with its subjective intensity, measured by the VAS scale (rho = 0.228; p = 0.044). Stronger discomfort caused by physical pain experienced coexisted with higher scores on indicators of emotional coldness, lack of empathy, hostility or associability.

Neither objective nor subjective pain indicators were related to the results of control lie scale and general level of quality of life (p > 0,05). Furthermore, extroversion corresponds to better life quality (rho = 0.295; p = 0.001), while neuroticism was linked to being prone to dishonest self-presentation, indicates by the scale of Lie (rho = –0.310; p < 0.001).

Table 2. Spearman's correlation between physical pain and psychological factors

	ALGOMETER	VAS	LOTR	EPQ-R(S)				SWLS
	Pain tolerance	Pain intensity	Optimism	Extraversion	Neuroticism	Psychoticism	Lie Scale	Quality of life
Pain threshold	0.412***	–0.025	–0.043	0.198*	0.007	–0.021	0.122	–0.019
Pain tolerance	–	0.073	0.068	0.217*	–0.180*	–0.149	–0.041	0.050
VAS (n = 79)		–	–0.071	–0.139	0.084	0.228*	–0.211	0.091
Optimism			–	0.234**	–0.166	–0.022	0.011	0.111
Extraversion				–	–0.166	–0.031	0.115	0.295**
Neuroticism					–	0.111	–0.310***	–0.146
Psychoticism						–	0.024	0.147
Lie Scale							–	0.100

* p < 0.05; ** p < 0.01; *** p < 0.001.

In addition, we examined the associations between pain threshold and tolerance and selected sociodemographic variables. Pain resistance was stronger among men, who achieved higher scores in tolerance (Z = –2.884; p = 0.004) as well as in tolerance (Z = –5.119; p < 0.001). Higher pain threshold was favored also by higher height (rho = 0.188; p = 0.031) and lower education level (rho = –0.254; p = 0.003), while greater pain tolerance – with higher height (rho = 0.471; p < 0.001) and body weight (rho = 0.353; p < 0.001), even besides BMI was not correlated with pain experiences. Neither senior's age nor place of residence were not correlated with objective pain sensitivity. Also subjective experiences, assessed by the VAS scale, did not associated to any of sociodemographic factors.

Discussion

The phenomenon of multimorbidity is associated with the aging process of the organism. With increasing age, the frequency of acute pain decreases, while the number of people reporting chronic pain increases. The severity of pain in this age group is influenced by a number of factors, including limited mobility, abandonment or restriction of social life, discouragement, loneliness, and depression (Singh, 2002). In this study, we aimed to examine the associations between pain experiences and three psychological variables-personality, optimism, and quality of life-in a very specific group of seniors over 61 years of age. Optimism and quality of life were not related to any of the pain measures, but three personality dispositions were found to be significantly related to goal setting. Among the seniors studied, extraversion promoted slightly higher pain threshold and tolerance, whereas neuroticism was associated with lower pain tolerance. Our results are consistent with other findings and thus support the hypothesis of a relationship between physical pain sensitivity and relatively stable personality domains. Individuals with high neuroticism scores have been found to have low pain tolerance, high pain intensity (Vassend et al., 2013), and high scores on self-reports of pain sensitivity (Bar-Shalita & Cermak, 2020; Quan et al., 2017. The same results were obtained for extroverts characterized by high pain tolerance (Ferracuti & De Carolis, 2005) and high pain threshold (Phillips & Gatchel, 2000). In turn, Lin et al. examined the relationship between general psychological distress and the presence of anxiety in chronic neck pain in the group of people with chronic diseases, which was confirmed by a positive correlation between neuroticism and chronic neck pain (Lin et al. 2010). In classical research, neuroticism has been associated with higher pain threshold and tolerance (Tajet-Foxell & Rose, 1995; Schailling, 1971). Neuroticism was also not differentiated in postoperative pain perception, while extraversion also emerged as significantly important (Lewandowska et al., 2016) . This discrepancy in results suggests that the relationship between personality dimensions and physiological responses are more complex than simple correlation data.

Other research reports suggest that neurotic and introverted individuals are less likely to report their pain because of significant personality limitations (Bond, 1971; Walding, 1991 Feldman et al., 1999), e.g., masking/hiding the pain response. Published evidence suggests that high levels of neuroticism and low levels of extroversion influence cognition and processes related to pain meaning, which in turn affect pain threshold and pain tolerance (Harkins et al., 1989; Newth & DeLongis, 2004).

In addition to these two main personality dispositions, a third - psychoticism - proved to be significantly important for subjective pain intensity. Seniors who scored higher on this domain were more likely to rate the pain they experienced as more painful than less psychotic individuals. Many studies have not found a relationship between this personality component and pain intensity (Cooper et al., 2000) but the most recent study by Davydov et al. (2021) showed that psychoticism is involved in conscious pain management by mediating pain coping strategies such as catastrophizing and cognitive distraction (Davydov et al., 2021). The presence of this relationship suggests that nociception processes may mask the effects of personality on pain threshold and tolerance. Thus, to better understand the independent influence of personality on pain, a thorough exploration of the origin of the personality-pain relationship is needed.

In our study, no relationship was found between optimism and pain sensitivity, but other studies with younger participants show that individuals with high levels of optimism expect positive outcomes for their future and are better able to cope with stress and everyday challenges (Carr, 2009). High levels of optimism are associated with better coping with stressful situations and better physical and mental well-being (Scheier & Carver, 1987; Scheier et al., 1994), so it can be assumed that it is associated with greater resilience to pain. Similarly, no correlation was found between pain sensitivity and quality of life, while such a correlation was found in studies by other authors (Laursen et al. 2005; Morgan et al.2003; Raiisi, 2020). One of the possible reasons for the observed differences could be the specification of the study sample. It is possible that the overall quality of life in the elderly is determined by a number of factors, so that in our group there was no correlation between objective and subjective pain measures as in younger participants.

Conclusion

Thus, our results support the notion that higher extroversion and neuroticism, in particular, may act as key personality traits that predispose older people to greater pain resistance and thus differentiate the experience of pain that cannot be avoided anyway. Personality may be one of the most important filters of individual pain interpretation, along with more biological temperament, which has also been shown to be an important modulator of pain experience.

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IMMEDIATE EFFECTS OF KINESIO-TAPING AND JOINT MOBILISATION ON SHOULDER IN OVER-HEAD ATHLETES WITH GLENOHUMERAL INTERNAL ROTATION DEFICIT

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Abstract The purpose of this study was to compare efficacy of kinesio taping (K-taping) and joint mobilization as immediate interventions for treating athletes with glenohumeral internal rotation deficit (GIRD). Thirty-two asymptomatic players were recruited from basketball, volleyball and handball who had a loss of shoulder internal rotation range of motion (IR ROM) of 10 degrees or more on their dominant compared to non-dominant side. They were randomly assigned to 1 of 2 groups: K-taping (n = 16) or joint mobilization (n=16). Participants in taping group were treated with K-tape for inhibition of external rotators of shoulder and participants in joint mobilization group were treated with grade four Maitland's mobilization technique for increasing glenohumeral internal rotation. Shoulder internal and external ROM were measured before and after the intervention with a universal goniometer. Both the methods produced significant improvement in IR ROM. The unpaired t-test showed significant change in IR ROM within both the groups (p = 0.003). No significant change was found on comparing both the groups (p = 0.373). There were no significant differences between results of the three sports (p = 0.592). K-taping and joint mobilization both are equally effective in improving the IR ROM in over-head players with GIRD.

Key words: kinesio taping, joint mobilization, GIRD, over-head athletes

Introduction

The glenohumeral joint (GHJ) is a ball and socket synovial joint consisting of the articulation between the head of humerus and glenoid fossa. The glenohumeral joint has sacrificed articular congruency to increase the mobility of the upper extremity and hand and is therefore susceptible to degenerative changes, instability and derangement (Levangie & Norkin, 2005). Players in overhead sports are required to perform repeated overhead movements and the glenohumeral joint must achieve extremes of range of motion, velocities and forces across the arc of movement (Dillman et al., 1993).

When the dominant arm is abducted 90 degrees, the GHJ external rotation ROM of the dominant arm is usually much greater than the nondominant arm (Borsa et al., 2008)thus exposing the overhead athlete to shoulder injury. Debate continues as to whether these altered mobility patterns arise from soft-tissue or osseous adaptations within and around the shoulder. Researchers have used quantitative techniques in an attempt to better characterize these structural adaptations in the shoulders of overhead athletes. Throwing athletes have been shown to display altered rotational range of motion (ROM. However, the total arc of motion (TAM) (the sum of maximum GHJ external and internal rotation ROM at 90° of abduction) does not always differ bilaterally. When compared to the nondominant shoulder, IR and TAM in the dominant shoulder may be reduced as a result of repetitive throwing. This leads to alteration in the GHJ arthrokinematics (Kibler et al., 2012). This loss of GH IR ROM at 90° of abduction in the dominant shoulder compared to the non-dominant shoulder is referred to as glenohumeral internal rotation deficit or GIRD. It can be as little as 10 degrees to as high as 25 degrees of deficit. According to research, overhead athletes with a shoulder IR limitation of ≥25 degrees have a 4 times higher chance of shoulder or elbow pain and injury, while those with a limitation of ≥10 degrees had a 2 times higher risk (Shanley et al., 2011).

It has been noted that overhead throwing athletes can expect a gain in external rotation and decreased internal rotation. It is most common in repetitive overhead throwing for the posterior shoulder musculature or ligamentous and capsular structures to become tight. This tightness can decrease an individual's ability to horizontally adduct the glenohumeral joint as well as impede internal rotation. Repetitive throwing can induce microtrauma to the ligaments in the posterior shoulder, making them more rigid and limiting movement (Mine et al., 2017).

The infraspinatus muscle contributes significantly to compressive forces at the glenohumeral joint and along with the rotator cuff muscles, serves an important role of being a static and dynamic stabilizer of the glenohumeral joint (Choi et al., 2017). Measurements of muscle activity indicate that the infraspinatus begins to become highly active at ball release, and the activity level remains elevated throughout the follow-through phase (Kotoshiba et al., 2021). Due to repetitive use of the external rotators of the shoulder: infraspinatus and teres minor in overhead throwing, the muscles are prone to over activity and muscle tightness resulting in possible reduction in internal rotation and increased external rotation.

Posterior-inferior GHJ capsule is hypothesized to become hypertrophied in over-head athletes due to the repetitive tensile stress placed on it during the arm deceleration and follow-through phase of throwing, creating a large force for the posterior shoulder to counteract. A tight posterior capsule is therefore one potential mechanism of shoulder impingement as it causes excessive anterior translation of the humeral head and minimize the subacromial space with consequent instability of the capsule (Rose & Noonan, 2018).

There were considerable amount of research findings addressing various interventions for treating GIRD in athletes. However, majority of them are focused on stretching the posterior structures. Keeping in mind the necessary adaptations which take place in an overhead throwing athlete's shoulder for them to perform optimally,

the purpose of this study is comparison of immediate effects of K-taping for fascia unloading and end range joint mobilisation for optimizing the arthrokinematic gliding and rolling movement of humeral head on overhead athletes with GIRD.

The need for this study stems from having taken into consideration the extremely common occurrence of GIRD in overhead players which makes them susceptible to shoulder injuries. Hence to find out immediate effectiveness of K-taping and joint mobilization on these players which can be practiced before their training or competition.

Material and Methods

Subjects

Thirty-two healthy male and female overhead athletes (height: 171.6 ±11.2 cm, weight: 75 ±5.6 kg, age: 21.2 ±5.6 years) volunteered for this study from Guru Nanak Dev University, Amritsar, Punjab. Institutional ethical committee approval was taken. A written consent form was taken by the subjects and the procedure was explained to them. Inclusion criteria included players with at least one year experience and are having a GIRD of minimum 10 degrees in the dominant arm. The players with a history of surgery or traumatic injury to the shoulders, if part of any rehabilitative exercise program for the shoulder joint or currently undergoing any prophylactic medical treatment were excluded from this study.

Procedure

Players were selected based on the inclusion and exclusion criteria. Independent variables in this study included age, level of participation, and dominant hand i.e., the arm used by the player to perform overhead activity in his sport. Dependent variable in this study was IR ROM. The measurement of IR and ER ROM of both the dominant and non-dominant arm with a universal goniometer (ISICO, Transparent, 360°) was carried out pre-intervention and post-intervention. players presenting with GIRD were selected to be a part of the study. To measure the shoulder rotation ROM the player was instructed to lie down supine on a firm plinth or bench with the shoulder in 90 degrees abduction and the elbow at 90 degrees flexion at the edge of the plinth and the goniometer was placed on the olecranon process. Three readings of ER and IR ROM were taken for both the arms and the average was calculated. After the assessment, the subjects were randomly divided into two groups, group A was treated with joint mobilization and group B was treated with K-tape.

Kinesio-Tape

Players were treated with K-tape for inhibition of external rotators of the shoulder: infraspinatus and teres-minor from insertion to origin with 15–25% stretch applied to the tape. All taping procedures were followed as described in Clinical Therapeutic Application Kinesio® Taping Manual 2nd edition. The subject was instructed to expose the required area and told to be in sitting position with his dominant shoulder and elbow flexed 90 degrees, internally rotated and horizontally adducted so as to apply a stretch on the external rotators. For inhibition of infraspinatus the tape was applied from its insertion: middle facet of greater tubercle of the humerus to the origin: infraspinous fossa of the scapula. For inhibition of teres minor the tape was applied from insertion: inferior facet of greater tubercle of the humerus to origin: lower 1/3rd of lateral border of the scapula. After tape application the subject was to sit in resting position and ER and IR ROM was checked again.

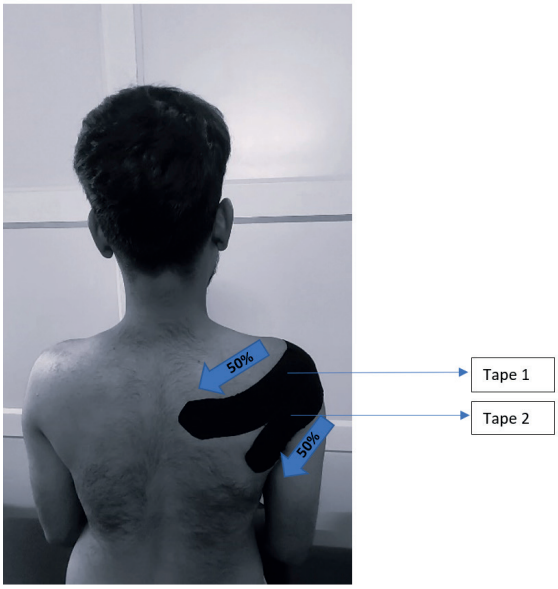


Figure 1. Demonstration of K-taping (posterior view) – Tape 1: Inhibition of Infraspinatus muscle and Tape 2: Inhibition of Teres Minor muscle

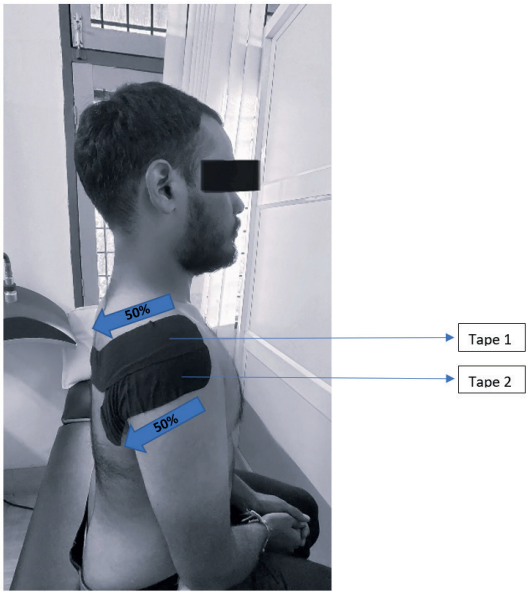


Figure 2. Demonstration of K-taping (lateral view) – Tape 1: Inhibition of Infraspinatus muscle and Tape 2: Inhibition of Teres Minor muscle

Joint Mobilization

Players were given end range GH antero-posterior (A-P) joint mobilization. Subject was positioned in supine with GHJ in loose pack position which is 55 degrees abduction, 30 degrees horizontal adduction and scapula stabilized. For the GHJ, Maitland's grade IV posterior glide mobilization was performed (small-amplitude rhythmic oscillations performed at the limit of the available motion and stressed into the tissue resistance). The 10 minutes intervention comprised 30 second mobilizations followed by 30 second rests. IR and ER ROM was checked again following 3 minutes rest after completion of intervention.

Figure 3. Demonstrating grade-IV A-P joint mobilization of GHJ

Statistics

The data was analysed using the SPPS software (version 16). Unpaired t-test was used to calculate the result between the two groups. Equal variances were assumed. The statistical significance was set at 95% confidence interval.

Results

The participants mean GH IR ROM for the throwing shoulder was 42.7 ±9.1 degrees and for the non-throwing shoulder was 57.3 ±8.5 degrees. The participants exhibited less GH IR ROM in the throwing shoulders as compared to the non-throwing shoulders. Both the methods produced significant improvement in IR ROM. Equal variances were assumed. According to the unpaired t-test significant change in IR ROM was found within both the groups ($p = 0.003$).

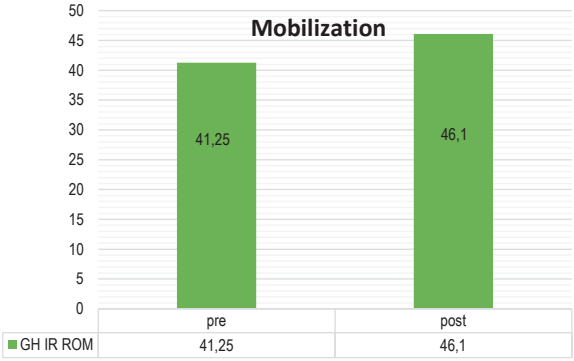
Table 1. Comparison of pre and post intervention data within the groups. Statistically significant association at $p \leq 0.05$

Groups	Pre-intervention IR ROM (mean ±SD)	Post-intervention IR ROM (mean ±SD)	t-value	p-value
Taping	42.7 ±9.1	45.1 ±7.6	3.266	0.003
Mobilization	41.26 ±11.8	46.1 ±5.6	3.266	0.003

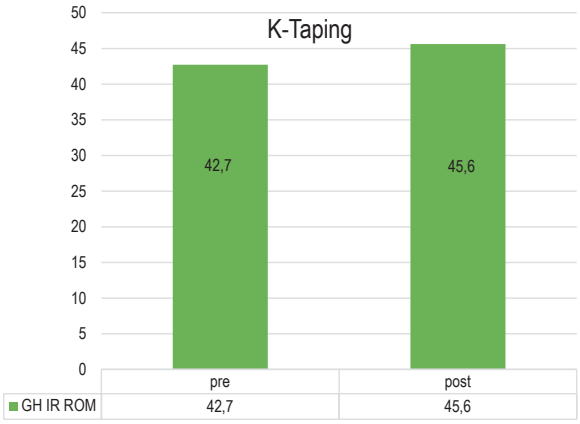
Table 2. Comparison between the two treatment groups. Statistically insignificant association at $p \geq 0.05$

Groups	IR ROM	P-value
Taping	45.6	0.373
Mobilization	46.1	

Graph 1. Comparison between post intervention IR ROM values for taping and mobilisation



Graph 2. Comparison between pre and post intervention ROM values for mobilization



Graph 3. Comparison between pre and post intervention ROM values for K-taping

Discussion

The over-head players in this study presented with a difference of 15.3 ±8.5 degrees less GH IR ROM in the dominant shoulders as compared to the non-dominant shoulders. This decreased range of GH IR is significant because players exhibiting GIRD of 10 degrees or more in the dominant shoulder as compared to the non-dominant shoulder are at a higher risk of injury and surgeries (Wilk et al., 2011). GIRD has been associated with posterior shoulder tightness mainly of the capsule, muscles, and ligaments. During the deceleration phase, there is a repetitive micro trauma to the posterior-inferior capsule which causes its contracture and thickening (Dashottar & Borstad, 2012). Osseous changes in the humeral head's centre of rotation also contribute to GIRD.

This study demonstrated improvements in GH IR ROM on the dominant side in both: taping and mobilization groups, but the difference between the groups was not statistically significant. The dominant shoulder joint in players had a GIRD of 15.3 ±8.5 degrees. Increment in internal rotation following the intervention were seen in both groups, which is in consensus with previous research concluding that internal rotation deficit is responsive to conservative treatments (Keramat & Babur, 2021) Mansehra, in 6-months duration. This quasi-experimental study recruited 120 young subjects with an equal proportion of males and females for four novel intervention groups (n = 30 each group

End range joint mobilization is a widely accepted intervention for improving range of motion of a restricted joint. Grade 1 distraction followed by end range joint mobilization for the glenohumeral joint was performed as intervention for treating GIRD in this study. The results demonstrate that joint mobilization technique significantly increased the glenohumeral IR ROM ($p = 0.003$) corroborating with previous literature (Yang et al., 2012) (Lin et al., 2008). Previous studies concluded that the end-range mobilization technique improves the flexibility of the glenohumeral joint capsule and stretches the soft tissue to induce an effect (Lin et al., 2008). Moreover, posterior gliding mobilization plays a role in normalizing the glenohumeral joint kinematics to ensure the humeral head glides in the appropriate direction (Manske et al., 2010).

The results of group B displayed an improvement in internal range of motion of shoulder ($p = 0.003$), ($t = 3.266$). Possible factors contributing to this include inhibition of muscles achieved by fascia unloading. The fascia

surrounding a muscle group which is involved in repetitive activity can undergo thickening and shortening of the superficial and deep fascia in order to provide more stability and allow the muscle to generate more power (Day & Venter, 2009). The ability of the endofascial collagen fibres to slide over one another would alter due to changes in the extracellular matrix of the deep fascia, such as those brought on by overuse syndromes, strain, and repetitive stress injuries. This would result in a change in stiffness. In addition to the mechanical or tensional reaction, a possible alteration in afferent signals is also to be noted (Day et al., 2009a) different hypotheses concerning the function of this resilient tissue have led to the formulation of numerous soft tissue techniques for the treatment of musculoskeletal pain. This paper presents a pilot study concerning the application of one such manual technique, Fascial Manipulation, in 28 subjects suffering from chronic posterior brachial pain. This method involves a deep kneading of muscular fascia at specific points, termed centres of coordination (cc. Ten times as many sensory nerve receptors are present in the fascial network as in red muscular tissue (van der Wal, 2009). This includes various different types of sensory receptors, including the myelinated proprioceptive endings (Golgi, Paccini, and Ruffini endings), but also the many tiny unmyelinated 'free' nerve endings which are found almost everywhere in fascial tissues (Themes, 2016).

The objective of K-taping is to facilitate muscle relaxation. When applying K-tape, the body segment is Sccplaced in a stretched position, so that return to a normal resting position will create skin convolutions. The lifting of skin is thought to promote subcutaneous blood flow and lymphatic drainage as well as unload the underlying fascia, allowing the underlying muscle to relax and possibly reduce their pain, however, In this study we included only asymptomatic athletes. K-tape can potentially affect the deep fascia layers (Day et al., 2009b) different hypotheses concerning the function of this resilient tissue have led to the formulation of numerous soft tissue techniques for the treatment of musculoskeletal pain. This paper presents a pilot study concerning the application of one such manual technique, Fascial Manipulation, in 28 subjects suffering from chronic posterior brachial pain. This method involves a deep kneading of muscular fascia at specific points, termed centres of coordination (cc which might reduce the susceptibility to microtearing of the tissue (Schleip et al., 2010). It may facilitate improved performance, especially in sports that require repetitive high-intensity muscular efforts and eccentric loading (O'Sullivan & Bird, 2011).

The effectiveness of sleeper and cross body stretching has already been proven to increase the IR ROM in several studies (Joseph & A.v, 2013) (Tawfik et al., 2022). However inadequate lengthening achieved by regularly performing the slow and sustained stretches increases the risk of fascia tearing (O'Sullivan & Bird, 2011). The use of K-tape in our study has not only eliminated this disadvantage but also produced significant improvements in the IR ROM. This is because it lifts the skin and fascia in order to release the underlying muscle and increase the strength of muscle contractility (Baker et al., 2011) as opposed to increasing its length, which due to its viscoelastic and thixotropic properties (Stecco et al., 2020) makes it highly prone to microtears when stretched quickly (e.g., high-intensity eccentric loading during the arm deceleration and follow through phases of throwing) (Jeswani et al., 2009)including plantar fasciitis, plantar fascia rupture, plantar fibromatosis, and plantar xanthoma, and illustrate them with appropriate magnetic resonance imaging (MRI).

Similar change in ROM was found on comparing both the techniques in our study ($p = 0.373$) which hence proves that an application of joint mobilization is equally effective to K-taping and can be used to improve IR ROM in overhead athletes with GIRD.

This current study was purely focused on interventional strategies for improving the passive internal rotation of the affected glenohumeral joint and the possible presence of suprascapular nerve injury would not alter the outcome of this study also there is lack of evaluation of shoulder muscles major limitation of the study.

Conclusions

As there is a possible association between GIRD and shoulder injuries, improving the GIRD may help in reducing the susceptibility to such injuries including internal impingement, scapular dyskinesia, SLAP lesions and UCL injuries of the elbow. This study concludes that both the techniques are equally effective in improving the IR ROM in over-head players with GIRD. A combination of both the treatment techniques can also be used for a better result and injury prevention as both are equally effective and act on separate structures. Therefore, before training or competition if a player has limited time, K-tape can be applied on the shoulder and if additional time is available then combined K-taping and shoulder mobilization can be given to the player by the therapist.

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