Original Article

Effect of cooling one side of a knee joint on one-legged vertical jump

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Abstract

The effects of cryotherapy on both muscles and joints have been studied using various techniques. The results on lower-extremity functional performance have been controversial. Replication of various aspects of previous studies, with appropriate modifications, will help to standardize cryotherapy interventions. The aims of this study were to examine the reliability of the single leg drop jump test and to evaluate the effects of 20 minutes knee joint cryotherapy application on the performance of this test in physical education students. Data were gathered using 52 subjects (age: 22.17 ± 1.53 year; body-mass: 74.83 ± 11.90 kg; Height: 1.78 ± 0.08 m). Twenty-two of them took part in reliability analysis of the single leg drop jump and all of the 52 participated in testing joint cooling effects. Reliability analyses were established by determining intraclass correlation coefficient and standard error of measurement. The sensitivity of agility tests was revealed by comparing standard error of measurement to the value of the smallest worthwhile change. The intraclass correlation coefficient that aims to assess relative reliability of the single leg drop jump was of 0.83. The standard error of measurement (7.65%) for absolute reliability was <10%. The single leg drop jump capacity to detect change is "good", its standard error of measurement (1.98) was smaller than the smallest worthwhile change (6.77). The 20 minutes knee joint cooling has not affected single leg drop jump height, immediately and 20 minutes after cryo-stimulation. The SLDJ is a reliable tool for the evaluation of vertical jump. A unilateral knee joint cooling does not produce any significant differences, between the pre- and the first post-cryo-stimulation single leg drop jump, as well as the pre- and the second 20 minutes post-cryo-stimulation single leg drop jump.

Keywords: - reliability; single leg drop-jump; cryotherapy; ice-application.

Introduction

In the field of sport, acute recovery strategies are a crucial factor in supporting supplementary training loads or competitions (Chaoyi, Zhaozhao, Minxiao, Fei, Yanan, Zhongwei, & Jiexiu, 2020). Thereby, recognition of the importance of recovery strategies for training adaptation, have prompted researchers to investigate in the effectiveness of various strategies to promote faster recovery from intense exercise (Kim, Lee, Choi, & Park, 2016). Some of the recovery strategies are collectively referred to as "cryotherapy" (CT). The CT is commonly used in sport, to accelerate recovery decreases muscle damage and inflammation markers (Abaïdia, Lamblin, Delecroix, Leduc, McCall, Nédélec, Dawson, Baquet, & Dupont, 2017; Grainger, Comfort, & Heffernan, 2019). The CT includes immersion in cold water/ice baths, topical application of ice, or brief exposure to extreme cold air (Chulvi-Medrano, LLana-Belloch & Pérez-Soriano, 2009; Fonseca, Brito, Silva, Silva-Grigoletto, Da Silva, & Franchini, 2016; Furmanek, Sobiesiak, Kajetan, & Rzepko, 2017; Hohenauer, Clarys, Baeyens & Clijsen, 2016; Kositsky, & Avela, 2020; Vieira, Siqueira, Ferreira-Junior, do Carmo, Durigan, Blazevich & Bottaro, 2016). The therapeutic use of CT, consists of withdrawing heat from the body by the lowering of tissue temperature (Bleakley, McDonough, & MacAuley, 2004; Knight, 1995; Murray, & Cardinale, 2015). The most common thermal agents used in CT are ice (packaged crushed ice), cold water (water immersion), cooling pads (gel packs), cold air, evaporating spray, or vaporized liquid nitrogen (Dykstra, Hill, Miller, Cheatham, Michael, & Baker 2009; Kennet, Hardaker, Hobbs, & Selfe, 2007; Swenson, Sward, & Karlsson, 1996).

The effects of CT on skeletal muscle (Fischer, Van Lunen, Branch, & Pirone, 2009), joint (Evans, Ingersoll, Knight & Worrell, 1995), and a combination of both muscles and joints (Burke, MacNeil, Holt,

MacKinnon, & Rasmussen, 2000; Kimura, Gulick & Thompson, 1997; Kinzey, Cordova, Gallen, Smith & Moore, 2000; Mattacola & Perrin, 1993) have been studied using various techniques. (Anderson, Gieck, Perrin, Weltman, Rutt & Denegar, C. 1991; Barber, Noyes, Mangine, McCloskey, & Hartman, 1990; Cordova, & Armstrong, 1996; Cross, Wilson, & Perrin, 1996; Davies, & Young, 1983; Demeritt, Shultz, Docherty, Gansneder, & Perrin, 2002).

Local Cryotherapy (LCT) is a CT mode that is increasing in popularity for its use in recovery of performance. It is also used as an integrated adjuvant treatment in the initial clinical management of musculoskeletal injuries, such as sprains, strains, lacerations, contusions of skeletal muscle, posttraumatic inflammatory disorders, and fractures.

Leg muscle power in general and vertical jump performance in particular, are considered as critical elements for successful athletic performance (Markovic, 2007). Jump performance includes performance of various types of body weight jumping-type exercises. The two most widely used are Squat-Jump and Counter Movement Jump (Fullam, Caulfield, Coughlan, McGroarty, & Delahunt, 2015; Mackala, Stodolka, Siemienski, & Coh, 2013). In addition to these two most classic tests, the Drop-Jump (DJ) is the most typical test of the plyometric panoply. The DJ can be bipodal or unipodal. (Bobbert, Mackay, Schinkelshoek, Huijing, & Van Ingen Schenau, 1986). The DJ places greater stress on the proprioceptive mechanisms than the SJ and CMJ tests. The effects of LCT on the performance of leg muscles during this high demand plyometric tasks are yet well studied.

LCT is frequently administered in either a static form, such as an ice bag, for a period of 15-30 min, or in an active form, such as ice cup massage, for a period of 10-15 min (Dykstra, Hill, Miller, Cheatham, Michael, & Baker 2009; Järvinen, Järvinen, Kääriäinen, Kalimo, & Järvinen, 2005; Jinnah, Luo, Mendias, & Freehill, 2019; Hunter, Ostrowski, Donahue, Crowley, & Herzog, 2016; MacAuley, 2001; Nolan & Michlovitz, 2005; Sarver, Sugg, Disser, Enselman, Awan, & Mendias, 2017). The results of these studies on lower-extremity functional performance have been controversial (Hohenauer, Clarys, Baeyens, & Clijsen, 2016). King and Duffield, (2009) and more recently, Hohenauer et al. (2016) reported no significant post-recovery vertical jump performance differences. Tseng et al. (2013) presented opposing data.

According to Lee et al. (2017), joint cooling seems to affect temporarily neural efficiency of the adjacent musculature. In previous studies (Cross, Wilson, & Perrin, 1996; Patterson, Udermann, Doberstein, & Reineke, 2008), bilateral 20-min LCT to the lower leg immediately reduced a single-leg (Cross, Wilson, & Perrin, 1996) and two-legged (Patterson, Udermann, Doberstein, & Reineke, 2008) vertical jump heights. Thus, bilateral joint cooling using ice bags still needs to be examined because ankle or knee joint cooling appears to facilitate activation of the plantarflexors and knee extensors, respectively, which are thought to be major concentric muscle groups during a vertical jump (Mackala, Stodolka, Siemienski, & Coh, 2013).

According to Atkinson and Nevill, (1998), the repeatability of performance on physical fitness evaluation tests, in test-retest research protocols, is strongly affected by the degree of reproducibility of the measurement tool. A test that is not highly reproducible is not an adequate test for trekking through variations in performance. To our best knowledge, only Lee et al. (2017) have verified the reproducibility of the used physical test before analyzing the effect of CT. In the other studies, the investigators declined to report on the reliability of the used functional tests (Fischer, Van Lunen, Branch, & Pirone, 2009; Pietrosimone, Hart, & Ingersoll, 2009; Pournot, Bieuzen, Duffield, Lepretre, Cozzolino, & Hausswirth, 2011; Schmid, Moffat, & Gutierrez, 2010; Vieira, Siqueira, Ferreira-Junior, do Carmo, Durigan, Blazeovich, & Bottaro, 2016; White, Rhind, & Wells, 2014). Thus, this study aimed to examine the relative and absolute reliability of the SLDJ, and investigated the immediate and short-term effects of 20 min of ice bag application to the knee on functional performance as measured by the SLDJ, in physical education students.

Material & Methods

Participants

Fifty two male physical education students participated in this study (age = 23.51 ± 3.21 years; body mass = 74.83 ± 11.79 kg; height = 1.78 ± 0.08 m; body mass index = 22.81 ± 1.88 kg.m²). They are consistently involved in regular physical activity. During the experiment, none of the subjects presented any significant pathology or trauma history that could affect the results of our study. All subjects voluntarily agreed to participate in the experiment after being informed of the objectives of the study and the experimental procedure. Prior to data collection and during a familiarization session, all subjects completed a full simulation of the experimental protocol. All participants were asked to avoid any strenuous physical activity before 24 hours and also the consumption of exciting products such as caffeinated drinks, dietary supplements, smoke, etc...

The experimental design was reported in figure 1. The experimental design was conceived to have two testing sessions. In session 1, the relative and absolute repeatability of the SLDJ were investigated. In session 2, were investigated the immediate and short-term effects of 20 min cryo-stimulation. All the trials in the two phases were completed under the same environmental conditions in a thermo-controlled laboratory (test/retest: 20.13 ± 1.95 / 19.2 ± 1.76 °C; test/retest humidity: 46.84 ± 7.36 / 45.84 ± 5.67 %; test/retest atmospheric pressure: 736.5 ± 5.43 / 765.62 ± 4.73 mmHg).

In Session 1, the relative and absolute reproducibility of the SLDJ was analyzed in 22 subjects (age = 22.77 ± 1.48 years; body mass = 71.39 ± 10.12 kg; height = 1.78 ± 0.06 m; body mass index = 22.51 ± 2.69 kg.m⁻²). In this session, every athlete repeated two SLDJ, twice with 24 hours interval and at the same time of day (± 1 hour).

In session two, 52 subjects (age = 22.17 ± 1.53 years; body mass = 74.83 ± 11.90 kg; height = 1.78 ± 0.08 m; body mass index = 23.49 ± 3.27 kg.m⁻²) performed three SLDJ tests: a reference SLDJ test performed just before the cryo-stimulation. A second SLDJ was performed immediately after 20 min of application of a 1 liter ice bladder on the knee (Figure 2). The third SLDJ was performed 20 min after the cryo-stimulation. During the application of the cold pack, a thin towel was placed between the ice bladder and the skin to prevent possible skin burns due to effect of the cold (Figure 2).

Fig. 2: Knee joint cooling

Single Leg Drop-jump (SLDJ)

To perform the SLDJ, the athlete was instructed to step on to the 30 cm box, step-off the box, landing between the two bars of the Optojump System, and immediately performing a maximal single leg vertical jump. To eliminate the erroneous effect of a sub-maximal effort, three SLDJ were performed at each time point, and the mean of the best two jumps was used for analysis. The trigger is evaluated from the take-off time measured by the "Microgate Optojump" system (Figure 3).

Fig. 3: Drop jump procedure: (1) starting-position; (2) landing between "Optojump bars"; (3) jumping off vertically; and (4) reception position

Statistical analysis

Data analysis was performed by SPSS™ version 18 (IBM, USA). The mean and standard deviation were calculated for each variable. In both sessions of our study, the normality of the distribution was verified by the KS test. In Session 1, the difference between the sample means of SLDJ test and retest was verified by a dependent t test. The effect size of the difference (dz) was calculated. The modified scale by Hopkins, (2000) was used. The effect size is Trivial if ($dz < 0.2$); small ($0.2 < dz < 0.6$); moderate if ($0.6 < dz < 1.2$) and large if ($dz > 1.2$). The relative reliability of the SLDJ was assessed by the intraclass correlation coefficient (ICC) and its absolute reliability was analyzed by the Standard Error of Measurement (SEM), calculated by dividing the SD of the difference between SLDJ test and retest scores by $\sqrt{2}$. The smallest Wirth While change (SWC) has been used and calculated as $0.2 \times SD$. According to Hopkins, (2000), when comparing SEM to SWC, test sensitivity in detecting systematic variation in performance status can be determined: $SEM < SWC$, the test capacity to detect change is considered "Good"; if $SEM = SWC$, it is considered "ok" and when $SEM > SWC$, the test can be rated as "marginal" (Liow & Hopkins, 2003). The SEM allows the calculation of the minimal detectable change at the 95% CI (MDC_{95}) according to the following formula: $MDC_{95} = SEM \times \sqrt{2} \times 1.96$ (Negra, Chaabene, Hammami, Amara, Sammoud, Mkaouer, & Hachana, 2017; Williamson, Lawson, Sigley, Nasypany, & Baker, 2019). The MDC_{95} determines the minimum amount of change in the measurement that would be required to exceed the level of measurement error and was expressed in absolute and relative term for comparison between agility tests. The time course of changes in the SLDJ performances was assessed by one way repeated-measures ANOVA. In addition, the values obtained were further evaluated by calculating the effect size. The classification of the effect size was determined by converting partial η^2 to Cohen's d . According to Cohen, (1998), d can be classified as small ($0.00 \leq d \leq 0.49$), medium ($0.50 \leq d \leq 0.79$), or large ($d \geq 0.80$).

Results

All the variables had normally distributed data. No statistically significant difference ($p = 0.28$) was observed between the SLDJ test and the retest. The inter-testing reliability of SLDJ was appropriate. SLDJ showed a very good relative ($ICC > 0.80$) and absolute reliability ($SEM < SWC$; $SEM\% < 10\%$) (Table 1).

Table 1. Measures of reliability for outcomes from two trials of a SLDJ ($n = 22$)

	test	Retest	dz	ICC	SEM	SEM%	SWC	MDC_{95}
SLDJ (cm)	25,52 $\pm$ 4.58	26,17 $\pm$ 5.08	0.23	0.83	1.98	7.65	6.77	5.49
SLDJ: Single Leg Drop Jump; SEM: Standard Error of Measurement; SEM%: Standard error of measurement expressed in %; SWC: Smallest Worthwhile Change; dz: Effect size; MDC_{95} : Minimal Detectable Change.								

The 20 min ice bag application has not reduced immediate and 20 min post application SLDJ performance in our subjects ($p > 0.05$). We did not observe any statistical significant changes in maximal SLDJ height between the pre-CT and post-CT kinetic profiles (Mean $\pm$ SD: 23.41 $\pm$ 5.58 cm vs 23.5 $\pm$ 5.21 cm vs 23.1 $\pm$ 5.85 cm; $p = 0.63$; $F_{(2,49)} = 0.41$; $d = 0.17$).

Discussion

This study assessed relative and absolute reliability of the SLDJ, and examined if a unilateral 20 min knee joint cooling alters SLDJ performance over time. The obtained results showed that, the SLDJ offers a reliable tool for the evaluation of vertical jump in young physical education students and that unilateral knee joint cooling does not produce any significant effect between the pre- and the first post-CT SLDJ as well as the pre- and the second post-CT SLDJ.

Establishing the reliability of a physical test is critical to ensure that changes in performance are interpreted appropriately (Hopkins, Schabert, & Hawley, 2001). A test is said to be reproducible when the results of the test are constant and stable during a test-retest procedure. When it is carried out twice in a row on the same subject, it must give the same performance (Quinart, 2013). Thereby, the first aim of Session 1 in our study was the quantification of the measurement error when performing SLDJ, to determine whether a change in an SLDJ scores after cryostimulation are real or is an artifact of measurement error.

The t test has not revealed significant differences ($t = 1.1$; $p > 0.05$; $dz = 0.23$) between SLDJ test and retest (Table 1). This result was confirmed by a $dz < 0.3$. Relative reliability is indicated by the magnitude of the ICC (Weir, 2005). It was good for the SLDJ test with an $ICC > 0.80$. Weir, (2005) recommends that the interpretation of ICC magnitude should be consolidated by absolute reproducibility analysis. Absolute reliability was indicated by the SEM in our study. The SLDJ showed an $SEM\% < 10\%$ (Table 1). We also calculated the likelihood that differences in SLDJ performance were substantial (i.e., SWC larger than the SEM) (Table 1). The SEM (1.98) for SLDJ was smaller than its respective SWC (6.77 cm) indicating that SLDJ has a good potential to detect real changes in maximal single leg vertical jump.

Using the SEM, a more useful means of interpreting absolute reliability is the MDC, defined as the smallest amount of reliable change in a measurement necessary to conclude that the difference represents an increase/decrease in performance that is not due to measurement error (Haley & Fragala-Pinkham, 2006; Wilkinson, Xenophontos, Gould, Vogt, Viana, Smith, & Watson, 2019). The MDC value of the SLDJ test in our athletes was 5.49 cm. To the others best knowledge no previous estimates of MDC for SLDJ test has occurred. The present research is unable to compare its results with previous findings.

The present study investigated the immediate and short-term effects of 20 min of ice bag application to the knee on functional performance as measured by the SLDJ. Many previous studies have also used the vertical jump as a test of functional performance; (Anderson, Gieck, Perrin, Weltman, Rutt, & Denegar, 1991; Cross, Wilson, & Perrin, 1996; Davies & Young, 1983; Fischer, Van Lunen, Branch, & Pirone, 2009; Petsching, Baron, & Albrecht, 1998) however; there has been an ongoing debate over use of the double-leg or the single-leg vertical jump for assessment purposes. The single-leg vertical jump is viewed as a test that more closely resembles the functional stresses placed on the body during athletic activities (Cross, Wilson, & Perrin, 1996; Isaacs, 1998; Risberg & Ekeland, 1994) which supports our rationale for testing the hamstrings by SLDJ. Our findings of a no effect in SLDJ height, immediately after the 20 min ice bag application and 20 min post-removal are in agreement with those of others (Atnip & McCrory, 2004; Melnyk, Faist, Claes, & Friemert, 2006; Tremblay, Estephan, Legendre, & Sulpher, 2001).

Melnyk et al. (2006) evaluated the effect of CT on the stretch reflex responses of the hamstring muscles induced by anterior tibial translation. As an ice-application, the used cold water-filled tube around the knee for 20 min and found no significant alteration in stretch reflex responses. Nevertheless, their experimental design did not reflect any functional activity and their results might therefore not be applicable to high demand motor tasks performed by an athletic population. Atnip & McCrory, (2004) studied the effect of 10 min of ankle-cryotherapy on joint kinematics and also found no effects. They concluded that 10 min might not have been enough time to cool down the joint area and to slow the nerve impulses. Tremblay et al. (2001) studied the effect of 20 min of quadriceps muscle cooling on weight discrimination using the quadriceps muscle and found no changes.

In contrast, other studies (Algaflly & George, 2007; Cross, Wilson, & Perrin, 1996; Fischer, Van Lunen, Branch, & Pirone, 2009; Kinzey, Cordova, Gallen, Smith & Moore, 2000; Richendollar, Darby, & Brown, 2006) have found decreasing effects of CT on motor performance and neuromuscular activity. Algaflly & George (2007) assessed changes in nerve conduct velocity of the tibial nerve, pain threshold, and pain tolerance after a crushed-ice application to the ankle joint for an average duration of 26 min. They found that CT could have an effect on muscular activity by significantly decreasing nerve conduct velocity. Other authors, studied the effect of 10 to 20 min of muscle cooling (Fischer, Van Lunen, Branch, & Pirone, 2009; Richendollar, Darby, & Brown, 2006) and whole limb cooling (Cross, Wilson, & Perrin, 1996; Kinzey, Cordova, Gallen, Smith, & Moore, 2000) on maximal high-intensity functional tasks. They all found significant decreases in performance during the used functional tasks.

Despite the discrepancies in the literature, in the present study, CT stimulation of the knee was found to have no significant effect on SLDJ performance in our subjects. Our findings are consistent with those of Halar et al. (1980) and Hopper et al. (1997), who found that neither nerve conduction velocity nor joint position sense were affected by a fifteen minute ice therapy session and with those of Kim et al. (2016) who also did not reveal any effect of 20 min local icing of the ankle and knee on the power of the lower limbs evaluated by a 20 m sprint and vertical jumping tests. We speculate that the duration of CT action and the amount of tissue cooled (i.e., leg, foot and ankle) may possibly be an underlying factor in the lack of effect of icing on SLDJ performance. While, CT is widely used by athletes, there continues to be ongoing debate in the specific literature regarding its efficacy as a post-exercise strategy to facilitate recovery from intense exercise. This is largely due to used protocols that are generally anecdotal and vary widely. Future studies are needed to resolve these methodological uncertainties, in the aim to optimize CT intervention in athletes.

Limitations

The key limitation of our study was that we studied non-injured physical education students. Therefore, the results must be interpreted as such, and cannot be applied directly to an injured population.

Conclusion

The results of our study revealed that, the reliability of the SLDJ is rated as "good" in physical education students. The SLDJ showed a very good relative and absolute reliability and a small MDC₉₅. Due to the current study findings, it was also concluded that, twenty minutes of superficial knee cooling treatment, has no effect on the SLDJ height immediately and 20 min after ice bag cryo-stimulation. The use of ice bag cryo-stimulation is an intriguing paradox for trainers who need to apply ice to the hamstrings without compromising functional performance. Further studies on the effect of local icing on short and intense efforts should be considered to consolidate the results of this study and to understand the effects of cryotherapy on lower extremity force production during functional movement.

Conflicts of interest

There is no conflict of interest including any financial, personal or other relationships with other people or organizations that have influenced the performance of this work.

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