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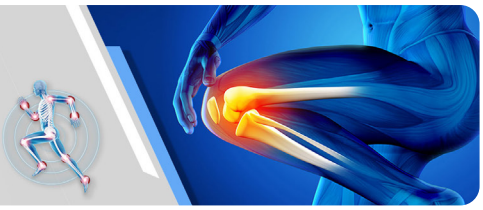

Whole Body Cryotherapy in Sport and Physical Activity: A Narrative Review

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Abstract

Cold therapy application is commonly used to relieve pain symptoms, to reduce inflammation in chronic diseases and damage in injuries at the musculoskeletal level. Two types of technologies, Partial Body Cryotherapy (PBC) or Whole Body Cryotherapy (WBC), are available in the market. This narrative review reports data from trials exploring WBC in Sport and in physical activity with the aim to show limitations and effectiveness in healthy subjects performing sport activity. The systematic search was conducted on the past ten years. The search keywords were "Whole Body Cryotherapy" OR "Cryogenic chamber therapy" OR "Cryostimulation" AND "Sport" OR "Exercise" OR "Athlete" OR "Physical Activity." The sample size, subject's age and gender, year of publication, duration and temperature of exposition, physical activity and outcomes were extracted. 15 articles met the inclusion criteria. Data on 265 subjects aged between 20 to 56 years were reported. The WBC protocols covered temperatures from -20 to -120 degrees Celsius. Exposure times ranged from 1 minute to 3 minutes. The cryostimulation sessions were coupled to normal daily recreational activities or, in the case of athletes, competitive activities during the competition season. WBC is a safe procedure and no major adverse events neither alteration of vital parameters were reported. The benefits have been found especially in post-exercise DOMS. Since many aspects need to be clarified a research agenda has been produced to answer crucial questions. In conclusion WBC seems to be a useful tool in Sport Medicine. However, further studies are necessary to establish standardized protocols.

Keywords: Cryostimulation; Whole Body Cryotherapy; Physical Activity; Sport; Athlete

Introduction

The beneficial effects of cold exposure have been known for a long time; ancient people well knew the positive consequences of assumption and use of cold water. Forty years ago, Prof. Toshiro Yamauchi recognized in his patients with rheumatoid arthritis, benefits upon their return from winter vacations in the mountains. He introduced, thus, cryotherapy in the clinical setting with good results obtained from the combination of cold and physical exercise [1,2]. Another particular form of therapy based on cryostimulation was proposed about 30 years ago for the treatment of the same rheumatic diseases [3]. Cold therapy, through both local and total body application in special and controlled chambers, is commonly used as a procedure to relieve pain symptoms, to reduce inflammation in chronic inflammatory diseases and to control damage in injuries and overuse symptoms at the musculoskeletal level

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[4-7]. Currently, cryostimulation is based on exposing part or the whole human body to extreme cold for a short period of time [7]. Therefore, two types of technologies, Partial Body Cryotherapy (PBC) or Whole Body Cryotherapy (WBC), are available in the market. The first system is referred to as cryosauna and is suitable for use by the individual to whom cryogenic fluid is vaporized around the body; the results of this kind of cryo application are not considered in the present study. In PBC the head remains outside the cold gaseous environment to preserve respiration [8]. On the other hand, so-called cryochambers regarding WBC consist of multiple rooms [1-3], in which the individual stays between 1 and 4 minutes depending on the protocol he or she follows, staying inside them with the whole body including the head. There are two types of cryochambers for WBC: one based on a gaseous environment using liquid N2 and the second one based on mechanical electrical refrigeration. In both, cold protection tools, such as gloves, socks and ear protectors, must be used. The present study is based on the results concerning WBC. In this system a subject starts with an initial acclimatization exposure in the first chamber standing along from 30 to 60 seconds at a temperature reaching -60°C, after that he moves on to the second cryostimulating chamber that lasting between 1 and 4 minutes with a temperature ranging from -100 to -180°C [9,10]. Post-exposure body temperature in a WBC chamber varies between 18 and 24°C depending on the individual [7,11,12]. Cryostimulation protocols are subjectively adapted based according to subject features and operator experience person; however, some guidelines to be followed by operators and subjects have been published [13].

WBC in Sport

The key to success in Sport, competitions and training consists in a well-organized growth program with appropriate and performing recovery strategies. There are various types of strategies to achieve good muscle recovery considering improvements in pain, fatigue, reduction in muscle damage, and downregulation in inflammation. Among these recovery techniques, WBC seems to have a positive impact on the whole body [14]. WBC has been introduced in medicine to decrease pain, inflammation associated with chronic pathological conditions, but it could be also useful to improve performance and recovery at the muscle level [15]. Among the various effects caused by exposure to WBC, data form literature report improvements in muscle strength, lower fatigue, improvements in sleep quality, and benefits in the injury-repair-regeneration cascade at the muscle level. Despite these effects, the impact given by WBC is to be further studied in view of the possible additional positive and negative effects of WBC [16-20]. In this narrative review we report various trials regarding WBC in Sport and associated with physical activity in aim to better understand its positivity, limitations and effectiveness in healthy subjects performing agonistic and non-agonistic sport activity.

Methods

The electronic and systematic search was conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) Guidelines through three databases. The databases used were PubMed, SportDiscus, and Scopus. The main search keywords were "Whole Body Cryotherapy" OR "Cryogenic chamber therapy" OR "Cryostimulation" AND "Sport" OR "Exercise" OR "Athlete" OR "Physical Activity." The following data related to the number and characteristics of participants (sample size, subject's age, and gender) were extracted; year of publication; description of the intervention (application characteristics, duration and temperature of treatment); level of activity; inclusion criteria; trial groups; outcomes; tools used to evaluate results and study results. The search included results from the past ten years. 15 articles met the search criteria after careful data analysis and extraction by PM. S. with the consultation of A.M. and F.M. The reasons for exclusion concerned duplicates articles, irrelevant articles, wrong outcomes, incorrect patient population or incorrect intervention and topics or not related. The search strategy is shown in Figure 1.

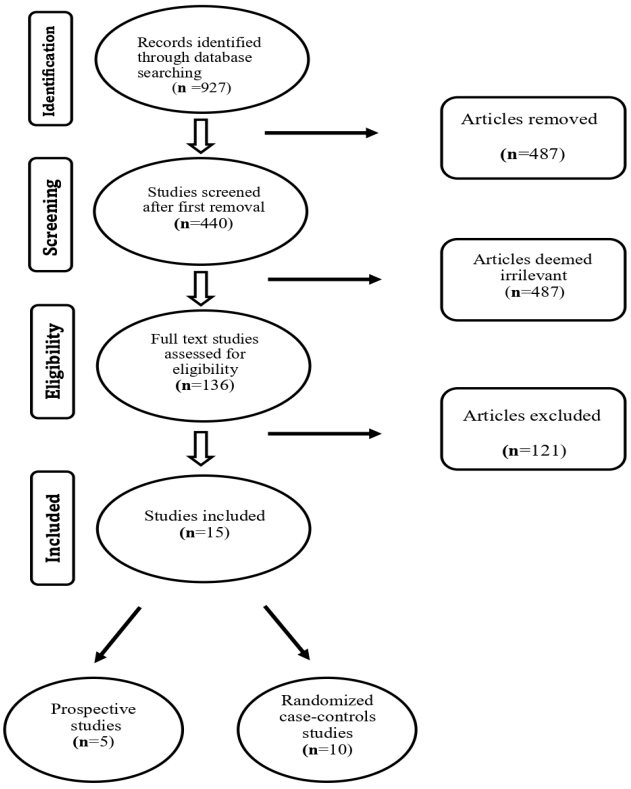

Figure 1: PRISMA flow chart.

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Results

In this paper 15 studies, 10 randomized case-controls and 5 prospective studies, met the inclusion criteria. Data about 265 (20 female and 245 male) participants, aged between 20 to 56 years were reported. Investigated subjects practiced from simple daily physical activity (10 trials) to competing as elite sports athletes (5 trials). The sports and/or training practiced were: soccer, skiing, running, cycling, motocross, some training protocols or simple daily recreational activity. A minimum amount of daily physical activity routinely practiced prior the entrance in the study was considered as inclusion criteria in order to associate with WBC practices during the study observations. Subjects with injuries or suffering from other clinical disorders with potential contraindication to physical activity and WBC, such as muscle or bone injuries, inflammatory disease, chronic pain or claustrophobia, hypersensitivity to cold, or heart problems were excluded. The protocols used in the trials differed from each other in temperature and time of exposure to WBC treatment. In this narrative review we extracted from the included studies only data related to WBC treatment and we excluded data related others applications such as PBC, WBH or CWI. The WBC protocols covered cryochamber temperatures from -20 to about -120 degrees Celsius. Exposure times were usually 1 minute in the first cold adaptation chamber and then increased from 2 to 3 minutes in the chamber at the lowest temperature. The cryostimulation sessions were coupled with various physical activity protocols corresponding to normal daily recreational activities or, in the case of athletes, competitive activities during the competition season. The endpoints of studies involved evaluations of the effects of WBC on various physiological aspects related and unrelated to physical activity: immunological, hormonal, and metabolic responses, but also differences between levels of strength, body composition, and post-exercise recovery. The parameters considered in the outcomes show no worsening post-exposure to WBC compared to baseline. No alterations of vital parameters or adverse events are found during and after exposition. The benefits are found in post-exercise DOMS (Delayed Onset Muscle Soreness) as WBC could improve the injury-repair-regeneration cascade process at the skeletal muscle level.

Table 1: Summaries of WBC studies.

Article	Type	Sport/ Activity	Level of Activity	Sperimental Group	Control Group	Temperature (°C)	Time of exposure	Endpoints	Results
Haq et al. [21]	RCT	Training programme	Not professional athletes	7	9	-120	3mins	Impact in strength or body composition or recovery	Not negative impact on strength or body composition
Coppi et al. [22]	Prospective study	Trained Runners	Not professional athletes	10		Not reported	2mins after 3 days schedule of training 60mins	Impact on cardiovascular changes	WBC did not affect cardiovascular response and can be safely used
Eda et al. [23]	Prospective study	Healthy active	Not professional athletes	6		(range between -150 -120)	3mins	To elucidate the effects of transient WBC on the expression of heat shock protein (HSP70) and the secretion of related hormones	A decrease in body surface temperature and an increase in noradrenaline and ACTH immediately after WBC, the core body temperature decreased 60 min after WBC, accompanied by an increase in HSP70 expression
Selleri et al. [24]	Prospective study	Soccer	Not professional athletes	9		-190	3mins	Determine the impact of cryotherapy on immunological, hormonal, and metabolic responses	WBC induces changes of hormone profile, hematologic parameters, and serum chemistry, in NPSP, suggesting a beneficial anti-inflammatory effect and a role in tissue repair

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Malone et al. [25]	Prospective study	Soccer	Professional athletes	16		(-133) (-120) (-114)	180s 173s 133s	Impact different levels WBC (temp and time)	Increasing levels WBC had no benefits
Haq et al. [16]	RCT	Downhill Run	Not professional athletes	26	15	-120	3mins post 1h run	Difference of impact post Downhill Run and WBC between Young and Old or High and Low-Fat People	WBC may alleviate muscle damaging post exercise
Nasi et al. [26]	Prospective study	Cyclists and Runners	Not professional athletes	20		-190	3mins for 3 times a day	Immunological, hormonal and metabolic responses	WBC induces beneficial changes in innate and adaptive immunity and promotes tissue repair
Zembron-Lacny et al. [15]	RCT	Athletes	Professional athletes	11	9	-120	3mins for twice a day for 7 days	Impact in skeletal muscle regeneration	WBC attenuated cascade injury-repair-regeneration of skeletal muscles
Michnik et al. [27]	RCT	Cross-country Skiers	Professional athletes	10	10	(-60/-120) (90)	(1/3 mins) (45mins) once time for 10 days	Difference impact between WBC/ WBH on the athletes	Post exercise changes of serum are similar but stronger in treatments post sauna
Bouzigon et al. [13]	RCT	Motocross Riders	Not professional athletes	10	8	(-25/-70)	(1/3 mins) after a simulated Motocross heat	Effect on recovery after a Motocross simulated exercise	WBC could accelerate muscular isometric strength and perceptual recovery after a Motocross heat
Douzi et al. [28]	RCT	Runners	Not professional athletes	22	22	(-25/-40)	(1/3mins) after 25mins run	Effect after evening training on sleep quality and heart rate	Improvement of subjective and objective sleep quality in physically active men with an unclear mechanism
Kojima et al. [29]	RCT	HIIT (High Intensity Interval Training)	Professional athletes	12	12	-140	(3mins after 10mins post exercise)	Effect on appetite regulation and energy intake	3mins of WBC after HIIT increased subsequent energy intake during a libitum buffet meal test
Kruger et al. [30]	RCT	HIR (High Intensity Running)	Not professional athletes	11	11	(-10/-60/-110)	(quickly at -10/-60 and 3mins at -110)	Effects on recovery during HIIT in a thermoneutral environment	WBC can improve acute recovery of maximal endurance performance
Wilson et al. [31]	RCT	Endurance training for Marathon	Not professional athletes	10 (WBC) 11(CWI)	10	(-85) (8)	(3/4mins) (10mins)	Comparison between WBC and CWI on recovery markers following a marathon	WBC had a harmful effect on muscle function compared to CWI after marathon. WBC improves perception of training stress compared to CWI. No influence was found on markers of damage or inflammation compared to placebo
Schaal et al. [32]	RCT	Intensified Training of Swimming	Professional athletes	10	10	(-10/-60/-110)	(quickly at -10/-60 and 3mins at -110)	Effects of daily sessions to prevent exercise and sleep-related signs of overreaching	WBC mitigate the signs of functional overreaching, such as reduced sleep quantity, increased fatigue, and impaired exercise capacity

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Table 2: Research Agenda.

Research agenda
To explore Gender difference in cryotherapy outcomes
Standardized protocol
Personalization of protocols according to subject characteristics
Duration of exposure
Range of temperature during exposure
Frequency and number of sessions
Determination of the appropriate timing of exposure for athletes: pre or post training or competition
To study the effects in performance and recovery post exercise
To evaluate the efficacy to recovery from injuries
To detect changes in biochemical and cardiovascular parameters according to different protocol od treatments and different subjects exposed to WBC

Discussion

Cryotherapy treatment, in the ranges considered (temperature between -20 and -120 °C and duration within the chamber between 1 and 4 minutes) and in relation to the participants in the studies of this review, seems to be a safe procedure, since no major or minor adverse events were reported. The individual studies contain few participants with a predominant distribution toward the male gender. Therefore, we have few data about effects of WBC in female gender. The number of cryotherapy treatments per subject is often in most of these studies is only a single session treatment. More than one has no consistent data of repeated or multiple sessions of WBC. Nevertheless, considering the good safety profile in both healthy people and athletes, the results seem to be promising. The various types of Sports and physical activity considered make the treatment affordable and show the variety of situations in which WBC could be used. Several and different protocols have been used and the need of a single or a few standardized models is needed. In support of these findings two "case-control random trials" [33,34] have studied a larger number of subjects, with a balanced composition between men and women, treated with different cryostimulation treatments and reported similar results. Also, in these studies the subjects, recreational athletes, experienced positive effects in muscle strength, physiological responses, and post-exercise recovery after exposure to PBC and CWI (Cold Water Immersion). Moreover, a recent metanalysis aimed to study the effects of CWI after exercise on fatigue recovery and performance showed the ability to reduce muscle soreness and accelerate fatigue recovery assessing delayed-onset muscle soreness, ratings of perceived exertion, countermovement jumps and blood plasma markers (DOMS, RPE, CMJ, CK, LDH) [35]. The parameter of post-exercise recovery is perhaps the most important outcome as well as the most researched in Sport activities. Even if is impossible to extrapolate a comparison the trend of WBC, in similar design trials seems to lead to similar conclusions or even be of added value. In consideration of the results achieved and the possible future implications of the use of WBC in Physical Activity in Sport, it would be important to better understand some fundamental aspects that are fundamental. Time and duration of exposure within the cryochamber, number of sessions and frequency of sessions, and timing of exposure, pre or post physical activity need to better define. According to actual data, the increased blood flow, caused by the vasodilation/vasoconstriction alternation is probably the mechanism to improve global muscle functionality. Studies are needed to better investigate the multiple effect involved of mechanism of action of cryoapplication. In addiction further comparative studies investigating the different effect of the multiple cryoapplication systems (WBC, PBC and CWI) are required.

Research Agenda

WBC could have numerous benefits on performance and various physiological aspects of the athlete, both in training and competition and in recovery from physical stress and injury. The large area of study is, at present, limited by the no standardized protocols for the use of cryotherapy practice. Based on the studies reported, it may be useful to base on some key aspects for future research. These indications will mainly be related to the physical activity/sport setting but future studies on non-active, pathological or injured subjects could also be helpful to determine the correct indications for WBC and its effects on the body. In WBC, it would be appropriate to work on several topics in order to answer key questions. It is necessary to increase the number of participants included in the studies with a balanced gender participation to detect gender difference in outcomes. There is a need for an uniform and standardized protocol according to subject characteristics. Key aspects such as duration and temperature of exposure, frequency and number of sessions need to be standardized. It is crucial to evaluate the best timing of exposure in athletes, pre or post training or competition, and to study the effects in performance and recovery from injury. It is necessary to evaluate effects on muscle activity, biochemical and cardiovascular aspects of the subject after cryotherapy treatments. Also, for the quality of life of both patience and athletes is relevant to study subjective aspects such as: fatigue, quality of sleep at night, and sensations after exposure to WBC. Moreover, it is mandatory to use also instrumental examinations such as Electromyography, Ultrasound or MRI to better evaluate objective WBC effects.

Conclusion

WBC seems to be a useful tool in Sport Medicine. Actual data confirm its high profile of safety. However, many questions need to be answered. Further studies are necessary to establish standardized protocols and to determine real

effects in performance and recovery after exercise and each sport activity.

Author contributions

PMS and AM: conception and design, data acquisition; drafting paper; tables and figure; final revision; final approval; agreement for all the aspects of the work. FM: conception and design, data acquisition; tables and figure. GAR, DD and JL: final approval; final revision. GB, RL and AMP: drafting paper; final revision; final approval.

Conflict of interest

The authors have no conflicts of interest directly relevant to the content of this review.

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