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1 **Title:** Thermography for defining efficiency of cryotherapy modalities in sport.

2

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11

12 **Comment on:** Alexander, J., Selfe, J., Birdsall, D., Rhodes, D. The effects of three different  
13 cryotherapy modalities on skin surface temperature across squad positions in a population of male,  
14 rugby union players. *Int J Sports Physical Therapy*. 2020;15(2): 210-220.

15

16 **Commentary:**

17 Infrared Thermal Imaging (TI) is well evidenced for the quantification of skin surface temperature ( $T_{sk}$ )  
18 and abundantly used within cryotherapeutic research (Kennet et al, 2007; Moreira et al, 2017; Alexander  
19 et al, 2020a; 2020b). We have published several articles recently on the effects of local cryotherapy  
20 with the physiological effects quantified through  $T_{sk}$  via TI techniques (Alexander et al 2020a; 2020b).

21 The remit of those studies was based on two key themes: (i)  $T_{sk}$  response to contemporary cooling  
22 modalities compared to traditional applications (ii)  $T_{sk}$  and physiological response to contemporary  
23 cryo-compressive devices with varying pressure adjuncts for the management of musculoskeletal injury  
24 or as a recovery strategy in sport. Comparison of traditional methods of cryotherapy modalities to  
25 modern alternatives in sport provided justification to progress the knowledge in theme (i). Literature  
26 to support theme (ii), was evidently lacking and developed naturally to combine multiple contemporary  
27 cooling modalities that operate cooling and compression simultaneously. All of which quantified  $T_{sk}$   
28 through infrared TI and followed guidance by Moreira et al (2017) for the setup of thermology capture.

29

30 Several investigations utilise infrared TI as an objective measure to quantify the efficiency of common  
31 cooling modalities used in sport by way of  $T_{sk}$ . Preferences on the choice of cooling modality often  
32 amount to whether optimal temperatures can be achieved in the target tissues and are quantified via  $T_{sk}$ .

33 In our recently published manuscript in the *International Journal of Sports Physical Therapy*  
34 (Alexander et al, 2020a), we aimed to determine differences in the cooling ability of three different  
35 cryotherapy modalities (Wetted Ice, Crushed Ice and CryoCuff<sup>®</sup>), in a specific sports population  
36 through physiological measures of  $T_{sk}$  using TI. Physical characteristics vary between playing positions  
37 in rugby union due to the demands of the game and in consideration of this, levels of adipose tissue

38 vary and influence interference on efficacy of local cooling applications. To date, although studies  
39 consider comparison of multiple cooling modalities, typically methods fail to report heterogeneities of  
40 participants or properties of the modality. A therapeutic temperature range for target  $T_{sk}$  following local  
41 cooling applications of 10-15°C has previously been proposed (Kennet et al, 2007). This typically  
42 represents a  $T_{sk}$  range whereby physiological responses occur and often referred to in publications  
43 related to cooling parameters achieved by cryotherapeutic modalities (Kennet et al, 2007). Results from  
44 our study (Alexander et al, 2020a) demonstrated differences in  $T_{sk}$  response to cooling with wetted ice  
45 displaying the greatest reductions. The main findings however highlighted not only the significant  
46 differences between  $T_{sk}$  when comparing between the three different modalities (Wetted Ice; Crushed  
47 Ice and CryoCuff®) but also across playing positions (forwards and backs). Results suggest using TI,  
48 to determine the effects of such variable (physical characteristics) is useful to consider in relation to the  
49 efficacy of cryotherapeutic applications in the assumption that adipose tissue levels vary between these  
50 positional characteristics. This may appear obvious, and cooling applications in terms of duration  
51 should be altered to account for the insulating effects of adipose tissue. That said, no evidence was  
52 available that compared contemporary cooling to traditional methods, nor contemplated the physical  
53 characteristic differences in playing position in specific sports populations at the time. Evidently,  
54 analysis using infrared TI results indicate that potential phase change differences alongside  
55 characteristic variables may both be responsible for variance in target  $T_{sk}$  responses (Alexander et al,  
56 2020a). In terms of an applied practical impact, individualisation of local cooling applications and  
57 choice of modality is imperative for optimal response. From an evidenced-based perspective, findings  
58 supported using TI, have implications on the development of what may be optimal protocols of cooling  
59 in sport through thermology assessment, however further research is required with methods of analysis  
60 considering individual response.

61

62 One tenet we did not consider in the study (Alexander et al, 2020a) was the effect of compression  
63 adjunct to each of the cryotherapy modalities applied. Pressure as a separate outcome was not quantified,  
64 however it is apparent from literature that compression may aid the magnitude of cooling. Evidently  
65 this has implications on modality choice based on  $T_{sk}$  quantification through infrared TI. Therefore,  
66 further to this work we investigated cryo-compressive applications measuring  $T_{sk}$  following application  
67 (Alexander et al, 2020b) utilising  $T_{sk}$  measures to determine differences between cryo-compressive  
68 modalities and cooling capabilities/magnitudes. This provided key evidence for theme (ii) presented  
69 earlier.  $T_{sk}$  results using infrared TI demonstrated differences in magnitude of cooling between  
70 modalities and pressure adjuncts, supporting earlier suggestions. Both studies (Alexander et al, 2020a;  
71 2020b) followed current guidelines by Moreira et al (2017) for use of thermographic imaging in sports  
72 and exercise medicine (TISEM). The rationale for discussing both Alexander et al, (2020a) and (2020b)  
73 in this commentary was to acknowledge the impact of pressure adjunct noted through  $T_{sk}$  from  
74 contemporary cooling modalities typically used in sport, quantified through TI. Considering the

75 findings, we propose that infrared TI provides an objective measure to quantify  $T_{sk}$  differences between  
76 various adjunct pressure options offered by contemporary pneumatic cooling modalities, as a safe non-  
77 invasive method. Comparison to other methods of thermology may be justified and while there is  
78 significant evidence of its use to quantify cooling applications typically applied in sport, recently the  
79 accuracy of TI has been challenged by Maley et al, (2020) suggesting overestimation of skin  
80 temperature through re-warming periods using TI. A counterpoint made by Havenith and Lloyd (2020)  
81 in the same journal however suggests this cannot be strongly affirmed based on current evidence.  
82 Furthermore with their methods being anatomically specific to the upper limb (Maley et al, 2020)  
83 findings may not be translational across other regions, i.e. the measurement of  $T_{sk}$  was performed over  
84 the upper peripheral limb, hand and fingers, not the lower limb such as in our studies (Alexander et al,  
85 2020a; 2020b) and the aim of their data was to compare against a skin thermistor. Although the authors  
86 might suggest that future studies should contemplate potential overoptimization of peripheral  $T_{sk}$   
87 through TI during rewarming periods and make appropriate adjustments where necessary to risk /  
88 withdrawal criteria (Maley et al, 2020), there are many approaches in which accuracy of thermographic  
89 cameras can be improved for their use in cryotherapeutic studies including; camera configuration,  
90 utilisation of reference values, greater number of temperature pixels or advanced camera technology,  
91 summarised by Havenith and Lloyd (2020).

92

93 In summary TI is useful in quantifying the physiological effects of cooling modalities on  $T_{sk}$ , however  
94 approaches for its use are dependent on the aim of the research. Individual measures of TI may provide  
95 useful data however future studies should consider multiple metrics that represent relevant parameters  
96 of investigation in sports-related cryotherapy investigations, beneficial simultaneously to infrared TI  
97 measures. Many studies do represent this, and we hope that future study design in our research group  
98 will continue to provide data with translational outcomes when investigating cooling protocols in sport.  
99 Consideration of individual response analysis rather than group average data is also important and  
100 would eliminate positional differences (as one example). Future studies could achieve these  
101 investigations through the utilisation of multiple metrics combining physiological, such as TI,  
102 biomechanical and psychological measures and individual data analysis, with the aim of greater impact  
103 to practice through optimal individualised approaches for contemporary cryotherapeutic applications.  
104 Evidently infrared TI is beneficial in challenging preferences of contemporary cooling applications in  
105 sport through thermography for decision-making, however further validation of methods is welcomed  
106 to provide accurate measurement of  $T_{sk}$  in the lower limb.

107

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