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Using thermal imaging to assess the effect of classical massage on selected physiological parameters of upper limbs

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Summary

Study aim: the aim of this study was to assess the relationship between classical sport massage of the hand and the forearm and the surface temperature of upper limb muscles, and between hand grip strength and the range of motion in the radiocarpal joint.

Material and methods: study participants comprised 35 women not engaging in competitive sport, aged 19–23 years. Thermal images were taken with a Flir A325 camera. Hand grip strength was measured using an analogue dynamometer. The range of motion in the radiocarpal joint was measured using a goniometer. All tests and measurements were performed twice: directly before and after the massage of the hand and the forearm (of the right limb). Classical massage was applied on the dorsal and palmar surfaces of the hand and on the anterior and posterior surfaces of the forearm.

Results: after the massage, the temperature of the right limb increased significantly, as did the temperature of the posterior surface of the left limb. However, no change in temperature was observed on the anterior surfaces of the left forearm and the left arm. A significant increase in the range of motion in the right radiocarpal joint (in all planes) was observed. No significant differences in hand grip strength measured with a dynamometer were found before and after the massage.

Conclusions: while classical sport massage increases muscle temperature, it does not improve effort capacity, and therefore it is not a sufficient means of preparing an athlete for physical effort. The massage increased the range of motion in the massaged limb, which mostly indicates the relaxing effect of the treatment.

Key words: Thermography – Massage – Upper limbs – Untrained women

Introduction

The aim of warm-up, regardless of its type and the activity that follows, is to prepare the person performing it for the upcoming effort and improve their effort capacity. Warm-up should result in, e.g., an increase in body temperature over the relaxed state (approximately 37°C). Two pertinent questions emerge: is it possible to confirm this phenomenon in a contact-free manner? And (more importantly), is warm-up an effective means of improving effort capacity? The latter question becomes even more pertinent if one takes into account that, as research has shown, improved effort capacity is not always accompanied by increased body temperature [21, 26].

Analysis of warm-up as a means of improving effort capacity shows that one of its fundamental effects involves an increase in body temperature, especially muscle temperature. This effect decreases what researchers sometimes refer to as *muscle resistance*, increases muscle fibre elasticity, and improves the ability of muscles to contract and relax [5, 6]. Furthermore, a properly conducted warm-up increases the range of motion in the exercised joints, which may considerably increase a person's effectiveness in the activity that follows [12, 24]. In this respect, the effects of warm-up can be examined by assessing muscle strength and the range of motion in selected joints.

The effectiveness of warm-up in terms of increasing body temperature can be assessed using thermal imaging, as applying invisible infrared radiation is a completely contact-free method of assessing changes in body surface temperature, especially valid since body surface lends itself well to observation due to its high emission factor ($\varepsilon = 0.98$). Moreover, changes in internal temperature

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manifest themselves in skin surface temperature because the latter is affected by the tissues of internal organs, the thermal conductivity of fat and muscle tissues, and the thermal emissivity of the skin itself. Thus, skin surface temperature is strictly related to internal organ temperature and the thermal properties of the analysed tissues. Consequently, thermal imaging may prove to have important diagnostic properties in such fields as sport and medicine, as a completely safe and non-invasive method [10].

Adamczyk et al. [2] assessed effort capacity after various types of warm-up, and found a correlation between the surface temperature of quadriceps muscles and jump height. Furthermore, Ding et al. [8] reported that the metabolism of active muscles can be assessed using thermal imaging. Measuring peripheral perfusion directly is complicated, and the usual methods of performing the measurement have numerous limitations, e.g., they cause disruptions of blood flow [13]. In contrast, infrared imaging is a reliable [7], non-invasive alternative that does not disrupt blood flow during measurements [25]. As a result, it may constitute an improved method of assessing muscle metabolism and blood perfusion in muscle tissue.

The main research aim of this study was to determine the relationship between classical sports massage of the hand and the forearm and the surface temperature of upper limb muscles, and between hand grip strength and the range of motion in the radiocarpal joint.

Material and methods

Study participants comprised 35 women not engaging in competitive sports. The mean age of the participants was 20.28 years (±1.57 years), mean body mass was 58.2 kg (±9.77 kg), and mean body height was 168.18 cm (±6.01 cm).

Thermal images were taken with a Flir A325 camera. The camera had a valid certificate, and was calibrated for repeatability and accuracy of measurements according to Glamorgan guidelines [4]. Special care was taken to always position the camera perpendicularly to the recorded object. The distance between the camera and the participants amounted to 2.5 m, ambient temperature amounted to 22–24 ºC, and humidity amounted to 48–50%. Humidity was determined with a hygrometer before each measurement [17].

Hand grip strength was measured using an analogue dynamometer. The range of motion in the radiocarpal joint was measured using a goniometer. All tests and measurements were performed twice: directly before and after the massage of the hand and the forearm (of the right limb).

Classical (manual) massage was performed on the dorsal and palmar sides of the hand and on the anterior and posterior parts of the forearm. The massaged person lay prone with a slightly abducted upper limb. Stroking and rubbing were used on the hand, and stroking, rubbing, kneading, and shaking were used on the forearm.

Empirical data were prepared using statistical tools, i.e., the arithmetic mean with standard deviation and the Wilcoxon matched-pairs test. Statistical significance was assumed at a minimal level of $p < 0.05$.

Results

The applied massage significantly increased surface temperature of the right upper limb, including the non-massaged sections, i.e., the arm. A significant change in temperature was also noted on the posterior surface of the (non-massaged) left upper limb. However, no changes in surface temperature were observed in the left forearm or the left arm (Table 1).

After the massage, the range of motion in the right radiocarpal joint increased significantly (in all planes). The left limb showed no changes in flexion, abduction, or adduction ranges. Only extension range showed a statistically significant change (Table 2).

Table 1. Surface temperature [°C] of upper limbs before and after massage

Limb	Side	Part of body	Before	After
Left	Anterior	Forearm	31.85 ± 0.83	31.81 ± 0.87
		Arm	32.31 ± 0.84	32.31 ± 0.67
	Posterior	Forearm	31.31 ± 1.01	31.56 ± 0.81*
		Arm	30.87 ± 1.07	31.60 ± 0.89***
Right	Anterior	Forearm	32.00 ± 0.8	32.40 ± 0.92**
		Arm	32.33 ± 0.7	32.57 ± 0.74
	Posterior	Forearm	31.62 ± 0.77	31.84 ± 0.81*
		Arm	31.12 ± 1.12	31.48 ± 0.96***

Significantly different than before massage: * – $p < 0.05$, ** – $p < 0.01$, *** – $p < 0.001$

Table 2. Range of motion [°] in radiocarpal joints before and after massage

Limb	Motion	Before	After
Left	Flexion	62.83 ± 14.03	65.21 ± 11.3
	Extension	61.86 ± 12.86	63.76 ± 10.73*
	Abduction	25.63 ± 6.28	25.83 ± 6.19
	Adduction	35.58 ± 7.65	36.33 ± 6.14
Right	Flexion	61.62 ± 13.5	65.48 ± 12.82**
	Extension	52.71 ± 11.82	57.74 ± 10.09**
	Abduction	23.37 ± 6.36	26.5 ± 6.02**
	Adduction	34.23 ± 6.42	37.00 ± 6.79*

Significantly different than before massage: * – $p < 0.05$, ** – $p < 0.01$, *** – $p < 0.001$

No significant difference in hand grip strength measured using a dynamometer was found before and after the massage (Table 3).

Table 3. Hand grip strength [N] before and after massage

Limb	Before	After
Left	206.86 ± 79.91	210.28 ± 83.44
Right	249.94 ± 78.81	242.62 ± 78.66

Discussion

A good argument for using thermal imaging in research on training is its past applications on the borderline between medicine and sports. We now know that the benefits of thermal imaging include detecting potential injuries and inflammations [20, 23]. Using this innovative and (most importantly) non-invasive diagnostic method to assess the effects of massage is especially valuable because of the method's applicability in everyday work.

Tissue massage is a form of therapy that involves exerting pressure on the connective tissue, muscles, and skin to stimulate them. A similar effect should occur in autonomous end organs that would restore the balance between sympathetic and parasympathetic elements of the autonomic nervous system [15, 16]. At the same time, massage should lead to the desired increase in body surface temperature. Massage and exercising have the common effect of increasing blood flow in a particular area of the body [19]. The massage applied in this study brought the desired effect, i.e., it increased body surface temperature, most likely due to local hyperaemia induced by the exerted pressure [14]. In turn, hyperaemia leads to increased temperature. Thus, the result obtained in this study seem encouraging from the standpoint of complementing or replacing warm-up with classical massage.

The observed changes in temperature concern not only the massaged areas, but also body surface temperature. Moreover, it seems that thermography can be used to non-invasively assess changes in blood perfusion and the effects of massage [22].

The methodology of conducting a warm-up states that body temperature can increase through purposeful activity (active warm-up) or passively on the part of the athlete (passive warm-up). Passive methods of increasing internal temperature involve external factors, e.g., a sauna, a warm bath, diathermy, massage, or poultices. The main advantage of passive methods is the fact that there is no need for the athlete to expend their own energy to increase their body temperature. So far, passive methods have been treated in sports primarily as complementary to active warm-up methods, and few studies have confirmed their effectiveness in preparing an athlete for exercise [3, 11, 18]. This study confirmed the aforementioned assumptions: on the one hand, the desired effect of increasing body surface temperature was achieved, and on the other, this effect proved insufficient to increase effort capacity.

It should also be noted that even though the massage brought the desired effect of increasing body temperature, the increase was different from that achieved in classical active forms of warm-up. Is has been proven that physical activity, including purposeful activity during warm-up, can increase body temperature, but does not necessarily involve an increase in surface temperature of the skin. Only several authors report a decrease in body surface temperature following physical effort (as a result of sweating and the evaporation of sweat from the surface of the skin) [1, 2, 3, 9, 10, 21]. This likely indicates that the human body is efficient at discharging heat. The observed decrease in skin temperature may also indirectly suggest increased effort

capacity. This effect was confirmed for numerous types of preparatory exercises used during warm-up [2].

Conclusions

1. While classical sport massage increases muscle temperature, it does not improve effort capacity. Nevertheless, it can constitute complementary treatment to classical (exercise-based) warm-up.
2. The results of this study show that thermal imaging can be a useful, objective, and non-invasive method of assessing the effect of massage on the human body.
3. The massage increased the range of motion in the massaged limb, which mainly indicates the relaxing effect of the treatment.
4. The obtained results form the basis for further research on larger, more diverse groups.

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