# INFLUENCE OF NEW ANATOMIC RING DESIGN ON PALM SKIN TEMPERATURE

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*Original article*

***Abstract***

*Gymnastics ring is very old that remained unchanged by shape (there were more changes in material and diameter) for more than 100 years. We made two new ring designs - one with the straight part to handle and one with the anatomic part to handle. New ring designs were compared with the classic ones during long swings in hang. All rings were of the same diameter and material, while the light distance between the upper and the bottom ring diameter was the same. Eighteen subjects were tested. Variables used were body height, body weight, body mass index, palm width and palm length, grip strength, and palm skin temperature before and after the exercise. Results show that palm skin temperature drops during long swing in hanging positions and this temperature drop is the most prominent with the classic and the straight rings. The palm skin temperature changes are not related to body mass index, relative grip strength, hand width and hand length and it seems that reasons for lower palm skin temperature can be related to the position of hands above heart and the shape of rings. In the sense of preserving good kinaesthetic awareness of the hand grip, at least for school and recreational use, the anatomic bent rings seems to be a better choice than classic rings or rings with the straight part.*

***Keywords:*** *artistic gymnastics, thermography, hand, grip.*

## INTRODUCTION

Gymnastic rings are the youngest male artistic gymnastic apparatus. However, at the beginning the design was triangular with the straight part for a handgrip (Eiselen, 1816) (Figure 1a). Soon it was changed into the circular design ("Nauk o telovadbi : vaje na orodji.," 1869) (Figure 1b) and at the World Championship in Prague (1907) gymnasts voted to use the circular rings design (Čuk & Karácsony, 2002). Since then the circular design was in use as well as defined and normed by the International Gymnastics Federations (FIG, 2015).

At the beginning the rings were made of iron, covered with leather, later they were made of wood (Spieth, 1989). More than 100 years long tradition had never been tested, whether it deserves the title of the most ergonomic apparatus. FIG changed in the past many apparatus norms, and the last most prominent was a change from the vaulting horse towards the vaulting table, mainly to increase the safety of men and women gymnasts (Čuk & Karacsony, 2004). Data on injury rates by the body part or apparatus related injury vary from authors and countries from where they come. Lower limbs are most frequently injured, mainly because of floor exercises, vaults and other apparatus dismounts, while the second most injured part are upper limbs (Lueken Lueken, Stone, & Wallach., 1993). From the practice rings are more often related to shoulders injuries, while wrists are not common injuries on rings, but there is no evidence how a ring design is related to injuries. According to Brewin, Yeadon & Kerwin (2000) rings must possess elastic properties in attempt to protect gymnast's joints and decrease the potential for injury. When a fist is formed for grasping, it forms an outward bowed shape that is almost exactly opposite to rings design (Figure 2a). The ring's circular design tends to concentrate weight and swinging forces towards the middle finger, with compressing palm skin also towards the middle finger, which is a personal experience of the authors.

Initially we wanted to redesign the rings in order to adjust ring grip to more anatomical hand characteristics. Two designs were prepared, one with the straight part for a hand, as it was originally used (Figure 2b), and another with the anatomic hand placement (Figure 2c). All designs were made of ash wood with the diameter of 28 mm and the same light distance between the upper and the bottom ring diameter (as it is the norm by the FIG)(FIG, 2015).

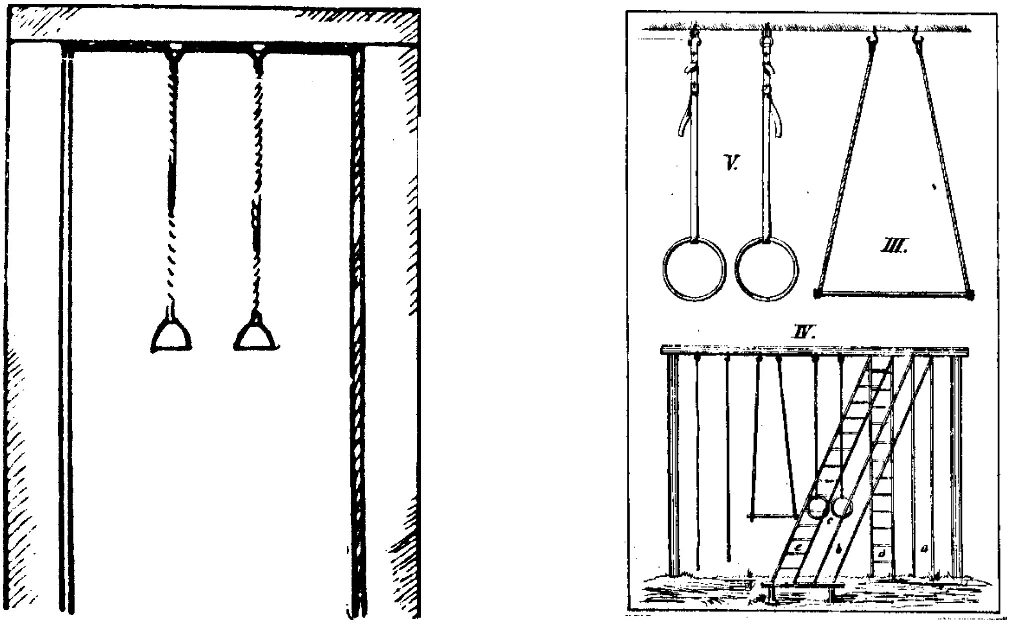


*Figure 1.* Shape of rings: a) triangular with the straight part – Eiselen 1844, b) circular – Nauk o telovadbi 1869.

*Figure 2.* a - palm grasp, b – rings with straight part, c – rings with bent part inward

*Figure 3.* Full long swing from backward to forward and to backward position.

As we know, the change of apparatus in a professional sport is a very long process (Čuk & Karacsony, 2004). We aimed to test the new apparatus designs for beginners and recreational gymnasts with very simple gymnastic activity – full long swings - with appropriate time duration.

In gymnastics the upper extremities are used as weight-bearing limbs causing high tensile and compressive impact loads to be distributed through the elbow, wrist and palm. The shape of the ring and its physical characteristics may have an important impact on these loads in the sense of friction and pressure forces to the palm and down to the shoulder. These forces combined with consequent palm skin temperature changes are could be involved in the development of wrist and palm injuries in gymnasts. The wrist is the second most frequently injured site in male gymnasts (Caine, Maffulli, & Caine, 2008) from pommel horse and impact supports (vaulting etc.), while there is no data how a ring design is related to this facts. The change of temperature measured by a thermal imaging technique could predict also inflammation or injuries (Plassmann & Belem, 2009; Sands, McNeal & Stone, 2011). When a gymnast has the hand contact with the apparatus, certain physical load applies to the hand. The most common loads are the force of body weight, grip force, friction force, and pressure. All of them have an impact on the change of palm skin temperature and with longer use also on palm injuries. Blisters are the most common palm injury. However, they are not mentioned among typical injuries, as they are not treated in medical centres (Dowdell, 2011; Sands, McNeal, Jemni, & Penitente, 2011).

According to Knapik, Reynolds, Duplantis & Jones (1995) blisters result from frictional forces (F-f) that mechanically separate epidermal cells at the level of the stratum spinosum. Hydrostatic pressure causes the area of the separation to fill with a fluid that is similar in composition to plasma but has a lower protein level. The magnitude of frictional forces (F-f) (which also produces heat) and the number of times that an object cycles across the skin determine the probability of blister development - the higher the F-f, the fewer number of cycles is necessary to produce a blister. Moist skin increases F-f, but very dry or very wet skin decreases F-f.

Gymnasts are using magnesium carbonate powder on their palms to make the handgrip with an apparatus safer (magnesium carbonate is very hygroscopic and dries palms). . For simple gymnastic elements on wooden apparatus in duration of less than 10 seconds, use of magnesium even rises the palm temperature, what makes use of magnesium carbonate slightly questioned in the sense of friction, but in the sense of lowering hand moisture its use is effective (Pušnik & Čuk, 2014). It is evident that exercise longer in duration should be performed with the use of magnesium carbonate. The aims of our research were to determine palm skin temperature change during the dynamic rings use, to determine which rings have more favourable design and to determine association between morphologic characteristics and grip strength with palm skin temperature change.

## METHODS

Our sample consisted of 18 students (9 males and 9 females), all master degree students of physical education course, average age of 22.3 ±1.2 years. All of them signed a written consent to participate in the experiment, according to the Helsinki declaration (WMA General Assembly, 1964).

We measured morphologic characteristics (body height (cm), body weight (kg), palm width (cm) and palm length (cm)) according to International Biological Program protocol (Weiner & Lourie 1981) on both sides, grip strength of left and right hand using a dial gauge hydraulic hand dynamometer (kg) (Lafayette professional hand dynamometer, model 5030l1, Lafayette Instrument Company, Lafayette, USA).

We measured chosen morphologic characteristics once as their reliability and validity is very high (Medved, 1980). For all subjects, we calculated Body Mass Index (BMI) and average results of the left and the right side regarding the palm width and the palm length. Grip strength was measured twice on the left and twice on the right side (Cronbach's alpha left 0.92, right 0.94). From the higher result on the left and the higher result on the right side grip strength we calculated the average. The reason to average the left and the right side values into joint variable was to lower bilateral differences (Čuk, Bučar Pajek, Jakše, Pajek & Peček, 2012) as they can be also the reason for differences in palm skin temperature. We calculated the relative hand strength as the maximum strength divided by the body weight.

We measured skin temperature with the thermal imager FLIR 650sc with the wide angle lens of 45°, detector resolution 640x480 and adjustable instrumental emissivity in steps of 0.01. The spectral range of the detector is 7.5 µm to 13 µm. The camera was calibrated in the range from 0 °C to 70 °C with the expanded uncertainty of 0.4 °C. In metrology, measurement uncertainty is a non-negative parameter characterizing the dispersion of the values attributed to a measured quantity. All measurements are subject to uncertainty and a measurement result is complete only when it is accompanied by a statement of the associated uncertainty with a known probability. Expanded uncertainty in metrology usually covers the range of results with probability of 95 %. The choice of a thermal imager was from its characteristics because we wanted to measure temperature accurately (Grgić & Pušnik, 2011). For accurate temperature that a thermal imager is calibrated with appropriate calibration method (Drnovšek, Miklavec, Pušnik & Batagelj, 2013; Miklavec, Pušnik, Batagelj, & Drnovšek, 2011). Calibration was performed in the Slovenian national laboratory for thermometry (University of Ljubljana, Faculty of Electrical Engineering, Laboratory of Metrology and quality), where the thermal imager was calibrated against the blackbody, of which the temperature was determined with a set of standard platinum resistance thermometers all of them traceable to the International Temperature Scale ITS-90. The laboratory performances are stated in the Key Comparison Database (KCDB) of the International Bureau for Weights and Measures (BIPM) in Paris. Thermal images were acquired in the gym hall with temperature of 21 °C and 45 % of relative humidity. In the analysis of thermograms the emissivity of skin with and without magnesium carbonate was set to 0.97. There is a lack of data for emissivity value of magnesium carbonate in this temperature and spectral range. We estimated its value similar to skin emissivity based on other similar materials (e.g. plaster) and based on its powder condition. Despite the use of magnesium carbonate during the exercise, we measured the palm temperature before swinging. The emissivity of skin was unchanged because after the swinging most of hands were without magnesium carbonate and thus we recorded correct values of temperature.

We measured the maximum temperature with one thermal image of the right palm and the left palm (whole area of fingers and palm) before and after the load and calculated their difference. We measured temperature of both palms because we expected thermal asymmetry in subjects due to different grip force and due to natural temperature asymmetry (Vardasca, Ring, Plassmann, & Jones, 2012). The imager was positioned at a distance of 2 meters from the measured object and placed in such a way that sunlight was not direct into thermal camera. Digital thermal imaging of human skin is important tool for acquisition of temperatures (Jones & Plassmann, 2002). For further analysis we used as the maximum palm temperature the average maximum temperature of the left and the right palm.

On the measurement day, we measured first the morphologic data and grip strength. Subjects were in gym hall for 45 minutes to acclimate on air conditions before they started to exercise. After that a subject was asked to use magnesium carbonate according to his/her needs (as exercised in the past), then stand in front of the thermal imager to the exact position, which was determined with the line on the floor. When the thermal imager took a thermogram, a subject went to the rings and performed long swings. After the eight full long swings, a subject dismounted in the defined area (the same place as the starting position before the exercise on rings) and showed the palms towards the thermal imager. A thermal image was taken 8 to 10 seconds after the dismount. Six subjects started with the exercise on the classic rings, six on the rings with the straight part and six on the anatomic bent rings, and then rotated to next rings to omit one sided skin exposure in a random fashion. Before and after each use of rings (classic, straight, anatomic) thermal image was recorded. Between each use of rings subjects had 20 minutes to rest. In each group were three males and three females.

Data were analysed using SPSS 22.0. Mean and standard deviations were used to present descriptive statistics following the Kolmogorov-Smirnov test for normality.

Pairwise t-test was used to evaluate the differences in palm temperature before and after the activity. Temperature difference (palm temperature after – palm temperature before activity) was also calculated and compared between different types of rings used in the study. Linear regression analysis was used to evaluate the possible correlations between palm temperature change on different ring types and body mass index, hand length, hand width and relative grip strength. All statistical significance was set at $p<0.05$.

## RESULTS

Kolmogorov-Smirnov test confirmed that all data were distributed normally. Table 1 represents the main demographic and anthropometric characteristics of the sample.

The linear regression analysis has shown that there are no statistically significant correlations between used predictors (body mass index, hand length and width and relative grip strength) and palm temperature difference measures on classic ($F=1.08$, $p=0.40$), straight ($F=1.41$, $p=0.28$) or anatomic rings ($F=0.69$; $p=0.61$).

## DISCUSSION

The main results of our study are indicating that there is a statistically significant palm temperature drop following the activity on gymnastics rings of different shapes (Table 2). In general while performing long swings palm skin temperature is lowering, although one would expect a temperature increase following the activity. One of the possible explanations of this observation is probably the hang position on rings where palms are kept highly above heart (more than 70 cm) causing a disturbance in blood flow to the hand. Low hand skin temperature was correlated with decrements in handgrip strength (Cheng, Shih, Tsai, & Chi, 2014) and has a negative effect on tasks which require speed, encouraging erroneous responses (Enander, 1987). Although, those studies were dealing with much lower palm skin temperature (14 °C and 5 °C, respectively) than were observed in our study they can still point out the possible consequences of the longer duration exercising on rings in hang position.

*Figure 4.* Same person right palm skin temperature classic rings (pre and after) and anatomic rings (pre and after)

Table 1
*Main demographic and anthropometric characteristics of the subjects.*

| | Mean | Std. Deviation |
|---|---|---|
| Height (cm) | 174.4 | 9.0 |
| Weight (kg) | 69.7 | 10.4 |
| BMI | 22.8 | 2.3 |
| HandWidth (cm) | 7.9 | 0.40 |
| HandLength (cm) | 19.1 | 0.91 |
| RelativeFmax in body weight) | 0.38 | 0.07 |

Table 2
*Palm skin temperature before and after activity.*

| Ring type | Palm temperature (°C) ± Std. Dev. | | Difference (°C) | t | Sig. |
|---|---|---|---|---|---|
| | *Before* | *After* | | | |
| Classic rings | 33.28±3.08 | 31.81±2.99 | 1.46* | 4.54 | 0.00 |
| Straight rings | 33.10±2.73 | 31.84±3.06 | 1.25** | 6.19 | 0.00 |
| Anatomic rings | 32.71±3.1 | 32.03±3.05 | .68 | 3.50 | 0.00 |
| Pairways t-test | | | | | |
| Classic | : Anatomic | | 0.78 ± 1.54 | 2.15 | 0.04 |
| Straight | : Anatomic | | 0.57 ± 0.99 | 2.45 | 0.02 |

Furthermore, we have also noticed some significant differences between ring types. While classic and straight ring types have shown similar temperature drops, the anatomic designed ring type caused a less temperature drop comparing to classic and straight ring type (Table 2). If high temperature drops may be indirectly related to poor performance as discussed above, than it seems that changing the ring type to anatomic type could have a positive effects on the athlete performance as the effects of palm temperature changes are not so prominent than with e.g. classic rings. The results of linear regression analysis further support this hypothesis, as predictors (such as BMI, hand width and length and grip strength) that could theoretically explain palm temperature changes were actually not correlated with these changes ($p>0.05$ for all instances).

Although researchers (Seo & Armstrong, 2008) have reported that normal force and contact area can be explained by the interaction between handle size and hand size it was not the case in our study as all rings used in the study were of same diameter of 28 mm and hand size could not have been a reasons for the observed palm temperature drops. Design of handles (e. g., shape, size, and surface) may help to increase people's torque strength, and elliptic handle shape shows as the best (Seo & Armstrong, 2011), in sense of elliptic handle shape we can state anatomic rings.

One of the drawbacks of our study is the fact that we did not measure friction and therefore we can only speculate about its effects in the light of our results (temperature drop). Prior to the experiment we expected that for wooden rings and very dry hands (palm with magnesium carbonate) friction should be reasonably high (O'Meara & Smith, 2002; Pušnik & Čuk, 2014) to cause an increase in palm temperature. However, the result of our study did not support our initial expectations and it seems that other factor could override the friction effect. Yamakoshi (2010) found that during kart racing, where handgrip must be firm, blood pressure measured with wrist sphygmomanometer significantly decreases immediately after the race. As mentioned above, one of the possible explanations of palm temperature drop could be the change in the palm blood flow during ring swings in hanging position. To evaluate this hypothesis we suggest that future studies should include a measurements of mean volume flow through radial artery using a duplex Doppler ultrasound as this method was used in other studies to evaluate the blood flow through radial artery (Kim et al., 2012). Our preliminary results (now shown) based on a single subject case study points toward the ring shape related changes in the blood flow during the static hanging on the ring.

## CONCLUSIONS

In conclusion our results show that palm skin temperature drops during swing in hanging positions and this drop is most prominent with classic and straight rings. The palm skin temperature changes are not related to body mass index, relative grip strength, hand width and hand length and it seems that reasons for lower palm skin temperature can be related to the position of hands above heart and shape of rings.

In the sense of preserving good kinaesthetic awareness of the hand grip at least for school use and recreational use the anatomic bent rings seems to be a better choice than classic rings or rings with the straight part.

## LIMITATIONS

The idea of rings with a different shape was predominantly prepared to serve better recreational gymnasts and school pupils with bare palms. It is not known what would be the effect of use handgrips and this can be the next stage in exploring of the new rings design. Also as we did not measure the support activity, therefore we can not confirm the new rings design as a superior in general terms.

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FIG. (2015). Apparatus Norms. Laussane: FIG

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