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Viewpoint

Does the warmup really reduce injury risk? Why we need new approaches to confidently answer this question

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1. The warmup reduces injury risk…or does it?

Coaches and players generally believe that the warmup may prevent injuries,[1,2] and research seemingly supports a preventive role for certain types of warmups (e.g., FIFA 11+, SHRed Injuries Basketball).[3–5] Although these are structured injury prevention programs (IPPs) designed to replace the routine warmup, the common belief is that any warmup helps reduce the risk of injury. However, there is an important gap between the interpretation of research findings on the benefit of warming up for injury risk and what the research on the topic has, in fact, responded to.[6] When practitioners state that the warmup prevents injuries, they are mostly considering the *acute* effects of warming up, not the long-term effects associated with specific IPPs (e.g., the FIFA 11+). When existing research shows that the warmup prevents injuries, it is mainly referring to the *chronic* effects of such IPPs when implemented as or during the warmup. Therefore, it fails to distinguish between effects attributable to warmup and effects from generally enhanced physical fitness components because of repeating that IPP over time. In this viewpoint, we discuss why this scenario has relevant implications for how we interpret research on warmup and injury prevention. Moreover, we discuss why a *chronic* preventive effect of an IPP that happens to be implemented during or as a warmup is potentially unrelated to the purported *acute* effects of warmup itself. Finally, we propose a different approach that may, in the future, assist to answer the question of whether purported warmup protocols reduce injury risk.

2. Chronic training effects versus acute warmup effects

Studies about the effects of the warmup on injury prevention usually compare a structured intervention with an alternative intervention or, more commonly, with a 'usual' or 'standard' warmup, even if these are often inadequately described.[7] Thus, the existing study designs are not truly assessing the acute effects of the warmup in injury prevention, but the long-term effects of IPPs. This constitutes a highly relevant research question and should be further pursued, but it does not help to answer whether a warmup acutely reduces injury risk. To better understand why this is true, we first need to abstract away the details of a wide body of research on the topic of warming up and injury prevention and focus on the commonalities. Fig. 1A exposes the general study design that has been commonly implemented. It becomes immediately apparent that these studies are not truly assessing whether a warmup is preventive of injuries, but whether a *chronic* IPP implemented during the warmup period may influence injury prevalence. This is admittedly a relevant endeavor, but the ultimate question being answered is "what are the *chronic* effects of an IPP" instead of "what are the acute effects of the warmup" on injury risk.

Some chronically implemented IPPs may even be more effective if also applied *post-training*, denoting that their effects are not truly related to "warming up", but simply to their chronic implementation as a training strategy. A cluster-randomized trial recruited soccer teams, all of which performed the FIFA 11+ as a warmup,[8] and the experimental teams also performed an additional 10 min of FIFA 11+ exercises *post-training* (see Fig. 1B). The pre- and post-training groups had significantly reduced injury incidence in comparison to the pre-training only group, so the injury reduction effect cannot possibly be attributed to the warmup per se. Currently, research aiming to investigate if the warmup reduces injury risk is using study designs that are incapable of responding to such a research question. How may we improve upon the current approach?

3. A refined study design to assess whether the warmup prevents injuries

In this section, we focus on the effects of the warmup in general, and not on specific IPPs. Therefore, the logic applies also to warmups whose main purpose is to improve performance or build team cohesion and are not necessarily aiming to prevent injuries. A simple solution would be to assess single-session interventions, where one group would warm up and the other group would not; then, both groups would perform the main training session, and the number of injuries would be assessed.

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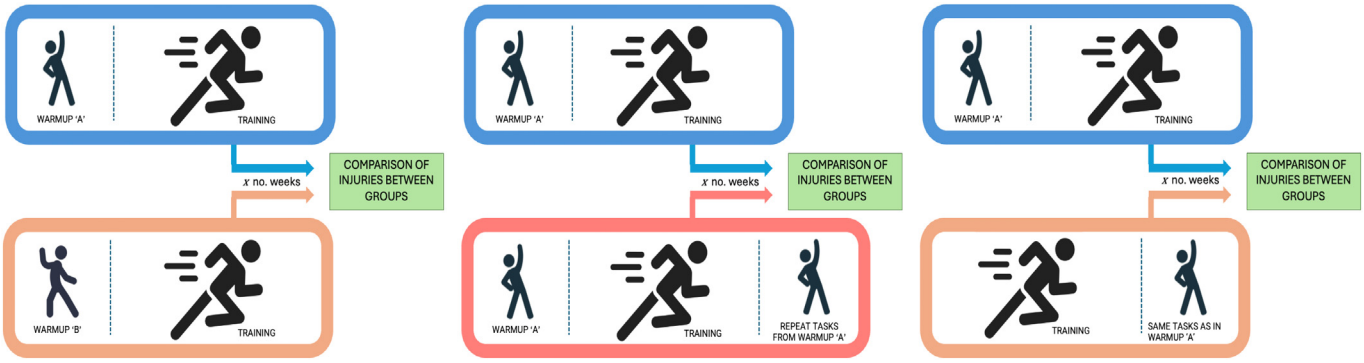

Fig. 1. A. Warmup and injury risk: prevalent (and problematic) study design. B. A different study design: when one group implements the warmup pre- and the same tasks post-training (non-volume equalized). C. A study design to assess whether the warmup prevents injuries (volume equalized).

Importantly, this does not mean we should expect the athletes to start the main training session with full intensity; instead, they would adjust the effort in the exercises and warmup during those exercises. The problem with this study design is that injuries are a relatively rare outcome, and it is common for a single training session to have zero injuries, or very few injuries that were due to external factors (e.g., contact injury between two players). For example, a ten-year epidemiological study with men and women's collegiate soccer players reported very low numbers of injuries per 1000 athlete-exposures, ranging from 0.79 (males, post-season) to 3.21 (males, matches).[9] This would result in severely underpowered studies, unless extremely large samples could be recruited. And there would be another potential problem. Injuries that occur in the initial phase of the training session might reasonably be attributed to lack of warmup, but what if those injuries occurred in the later part of the training session? Could we still realistically attribute the cause to a lack of warming up? Indeed, if the warmup generated more fatigue than performance enhancement,[10] these later injuries could have been promoted by an overly long and/or intense warmup.

Perhaps a compromise can be reached, using a traditional *chronic* study design, where large samples would still be beneficial, but not necessarily as decisive as in acute studies (as there is more time involved, and so more injuries will likely occur, facilitating statistical analysis). However, we propose a twist in its structure, to clearly differentiate between the warmup effect, and the chronic effects of an IPP (which are not warmup-related). A chronic study comparing warmup to no warmup[6] would result in a large, relevant difference in accumulated training volume and exposure to certain specific stimuli (i.e., the exercises performed by the warmup group, but not by the controls). In that scenario, any injury-related claims could be explained due to differential training stimuli. Therefore, we propose a dose-equalized chronic study design that may still allow inferring something about the effects of the warmup on injury prevention (see Fig. 1C).

Both groups would be exposed to the same training stimuli (i.e., the prescribed exercises and their dose). However, one group would perform the warmup as expected (i.e., pre-training), while another group would perform the same protocol post-training. To avoid logistic issues with the main training session, especially in team sports, one group could arrive earlier to perform the warmup, then both groups would perform the main training session, and finally the other group would stay after that session to perform the same intervention. Ethically, this design is perfectly justifiable. First, "no-warmup" conditions are not universally inferior to warmup conditions performance-wise,[6] and so it is unclear whether this will pose an additional injury risk. Second, by merely engaging in the main part of the training session, the athletes will naturally warm up during the proposed activities, even if no formal warmup is being performed. Therefore, a warmup will inevitably occur through, even if those activities are not being formally termed "warmup". Third, to assess the accuracy of statements regarding the preventive effects of the warmup, we must put this to the test directly. The concept could initially be tested at lower competitive levels, where practitioners may be more open to novel procedures, as they may not be so constrained by competitive demands. If the initial results are promising, the concept could later be tested at higher competitive levels.

We suggest this design to be applied only in training sessions, as the warmup for official matches often has other goals (e.g., adapting to the space and environmental conditions) and may have specific requirements depending on the competition (i.e., certain competitions impose certain official warmup protocols or routines).[6] Therefore, such a study design would only be implemented in training sessions and not before official matches. Our proposed study design would further allow establishing a formal scientific hypothesis: if the warmup has an expected effect on injury prevention, then the group performing the pre-training protocol should have less injuries than the group performing the post-training protocol. Any other outcome would directly contradict the claim that the warmup is mandatory from an injury prevention standpoint. As a potential downside, it is possible that players in the pre-training warmup group engage with the main training session at an increased intensity in comparison to the post-training group. Alternatively, the players that have engaged in the warmup may have to adjust their level of participation to sub-maximal intensity. Regardless, we doubt this would have a serious impact, with the control group likely requiring only a few minutes to keep up with the intended pace.

4. Concluding remarks

Injury prevention is only one of many goals of a warmup, perhaps its most controversial.[6] As shown in this viewpoint, current study designs used by research on the topic may provide support for the chronic preventive role of certain IPPs but fail to support a preventive role for the acute effect of the warmup itself. We propose a simple, but potentially effective study design to better evaluate such a research question: it maintains the statistical advantages of being a chronic intervention, guarantees training dose equalization across groups, and allows testing a very specific scientific hypothesis. The proposed design has three potential outcomes, of which only one would support a preventive role of the warmup: the pre-training warmup group would need to have less injuries than the other group. An equal or superior injury rate would fail to support a preventive role for the warmup.

Confirmation of ethical compliance

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CRediT authorship contribution statement

José Afonso: Conceptualization, Project administration, Supervision, Writing – original draft, Writing – review & editing. **Konstantin Warneke:** Writing – review & editing. **Lars H. Lohmann:** Writing – review & editing. **Tania Pizzari:** Visualization, Writing – review & editing. **Daniel Boullosa:** Writing – review & editing.

Declaration of interest statement

The authors have no competing interests.

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