INTRODUCTION

Stretching is commonly used for improving the end range of motion of a joint, and includes a variety of methods, one of which is ballistic stretching (bouncing through the end range of motion of a joint) (Page, 2012).

Ballistic stretching is often conflated with dynamic/active stretching. Dynamic/active stretching refers to a swinging motion that does not emphasize end range of motion, such as arms swings and pendulum leg swings. For the purpose of this paper, we will refer to ballistic stretching as that which specifically involves bounces through the end range of motion (Weerapong, Hume, & Kolt, 2004).

Short-term ballistic stretching protocols have been shown to effectively improve range of motion (Witvrouw, Mahieu, Roosen, & McNair, 2007) and sports performance (M. T. Woolstenhulme, Griffiths, Woolstenhulme, & Parcell, 2006). Its mechanisms for improving range of motion are distinct from and complimentary to those involved in static stretching; it has been recommended that ballistic and static stretching be combined for tendon injury prevention programs (Witvrouw et al., 2007).

However, there exist admonitions against the use of ballistic stretching (Bird, 2012) (Page, 2012) based on the theory of an increased risk of injury. However, there has never been a single study showing an increased risk of injury with ballistic stretching. In addition, the only study to attempt to directly evaluate the risks of ballistic stretching has

shown reduced DOMS with ballistic stretching as compared to static stretching (Smith et al., 1993). In addition, the ACSM has recommended ballistic stretching for adults (Medicine, 2013).

It has been observed that there lacks a proper scientific consensus on the safety of ballistic stretching (Weerapong et al., 2004). Given the apparent benefit of ballistic stretching but lack of research on its safety, the purpose of this review is to examine the literature to find controlled studies reporting injuries with ballistic stretching and, where possible, compare them to static stretching injury rates.

METHODS

A search for "ballistic stretching" was performed in Pubmed and Sportdiscus databases. Titles, abstracts, and full papers were screened for relevance and inclusion criteria.

Studies from published journals were included if they included a ballistic stretching condition which specifically stated that there was bouncing at end range of motion. Figure 1 shows the flow-chart of inclusion/exclusion.

To determine injury outcomes, all included papers were searched for terms related to injury: "injur-" (injury, injuries, injured), "drop out", "DOMS", "sore-" (soreness), and "pain".

Figure 1. Flow chart of paper inclusion/exclusion

RESULTS

A total of 65 titles were retrieved and screened, resulting in 25 abstracts to be read.

Of these abstracts, 1 paper was rejected for being a review paper (Witvrouw et al., 2007) and 1 paper was rejected for being non-English (HAYAKAWA, TERADA, & MIAKI, 2014). This resulted in 23 papers being screened for ballistic stretching methodology.

12 papers (Smith et al., 1993) (Sá et al., 2015) (Eguchi et al., 2014) (García-López, Izquierdo, & Rodríguez, 2010) (Bacurau et al., 2009) (da Conceição Dos-Santos, Costa, & di Masi, 2014) (Douvis, Tsiagganos, Smirniotou, Zacharogiannis, & Tsolakis, 2011) (Wiemann & Hahn, 1997) (Beedle & Mann, 2007) (Kirmizigil, Ozcaldiran, & Colakoglu, 2014) (Wallmann, Christensen, Perry, & Hoover, 2012) (Warren, Coble, & O'Brien, 2014) were subsequently rejected due to ballistic stretching methodology (either not specifically describing bouncing at end range of motion / through a point of mild discomfort), resulting in 11 papers retained (Covert, Alexander, Petronis, & Davis, 2010) (Konrad & Tilp, 2014) (M. T. Woolstenhulme et al., 2006) (LaRoche, Lussier, & Roy, 2008) (MAHIEU et al., 2007) (LaRoche & Connolly, 2006) (Barroso, Tricoli, Santos Gil, Ugrinowitsch, & Roschel, 2012) (Bradley, Olsen, & Portas, 2007) (Jaggers, Swank,

Frost, & Lee, 2008) (Samuel, Holcomb, Guadagnoli, Rubley, & Wallmann, 2008) (Unick, Kieffer, Cheesman, & Feeney, 2005).

Short-term Protocols

6 papers (Covert et al., 2010) (Konrad & Tilp, 2014) (M. T. Woolstenhulme et al., 2006) (LaRoche et al., 2008) (LaRoche & Connolly, 2006) (MAHIEU et al., 2007) used short-term protocols ranging between 4-6 weeks, 3 of which explicitly reported injuries (Konrad & Tilp, 2014) (LaRoche & Connolly, 2006) (MAHIEU et al., 2007).

Mahieu et al. (MAHIEU et al., 2007) had 96 subjects separated evenly into 3 conditions: ballistic, static, and control. Both stretching groups performed the classic standing wall stretch for the plantar flexors every day for a period of 6 weeks. The static stretching group held the back knee completely extended, whereas the ballistic stretching group bounced through this position at a rate of 1 Hz. Stretches were performed 20 seconds on, 20 seconds off, for 5 sets. There were 6 drop-outs reported due to injury or illness, but no further information was provided.

Konrad & Tilp (Konrad & Tilp, 2014) had 48 subjects evenly divided into ballistic stretching and control conditions. Subjects of the ballistic stretching group performed the same wall-assisted bouncing stretch (1 Hz, for 30s x 4 sets) of the plantar flexors 5 times per week. The ballistic stretching and control conditions each had 3 subject drop-outs due to injuries.

LaRoche & Connolly (LaRoche & Connolly, 2006) had 29 subjects separated into 3 conditions: control (10 subjects), static (9 subjects), and ballistic (10 subjects). Both stretching groups performed a standing hamstring stretch 3 times per week, for a period of 4 weeks. The static stretching group held the stretch at a point of mild discomfort for 30 seconds, for 10 sets. The ballistic stretching group used momentum to bounce into the stretch at a rate of 1 Hz, pushing to a feeling of mild discomfort, for 30 seconds, for 10 sets. They reported that "No participants in either the static or ballistic stretching group experienced any muscle strain other than DOMS".

Three papers (Covert et al., 2010) (LaRoche et al., 2008) (M. T. Woolstenhulme et al., 2006) using longitudinal ballistic stretching protocols did not report any injuries.

Acute protocols

5 papers used acute stretching protocols in warm-ups (Jaggers et al., 2008) (Samuel et al., 2008) (Barroso et al., 2012) (Bradley et al., 2007) (Unick et al., 2005). No injuries were reported in any of these papers.

CONCLUSION

There are no studies specifically addressing the injury risks of ballistic stretching and limited studies providing detailed injury rates for ballistic stretching. No study included a statistical analysis of injury risks of ballistic stretching.

In most papers, injury rate was not relevant enough to report. In the few papers where injury was reported, the risks of ballistic stretching were comparable to those of static stretching or control groups.

The only study specifically examining injury risk of ballistic stretching was not included in this review due to an unclear methodology (Smith et al., 1993). This single study suggests that ballistic stretching produces less tissue damage than static stretching.

Given the complimentary roles of static and ballistic stretching in creating soft tissue adaptation and improving flexibility (MAHIEU et al., 2007), further attention should be given to ballistic stretching.