

Review Essay

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A systematic review of the effects of laughter on blood pressure and heart rate variability

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Abstract: In this systematic review, we sought to understand the effects of laughter-inducing interventions on blood pressure and heart rate variability. For this purpose, we identified 32 relevant records through database searching. The results suggest that laughter is associated with a decrease in blood pressure in pre–post measurements. However, this association varies according to the type of intervention delivered and the characteristics of participants. In controlled between-groups comparisons, the effect of laughter-inducing interventions on blood pressure was found to be non-significant, which can be due to the small number of studies available and its high level of heterogeneity. In studies involving heart rate variability, the most consistent findings point to an association between laughter and decreases in both frequency (LF/HF) and time-domain (SDNN) indicators. Longitudinal studies suggest that laughter frequency is associated with improved cardiovascular health. Several studies presented sub-optimal levels of quality, and more research is necessary to examine the impact of individual and intervention-related factors in the effectiveness of laughter-inducing interventions in cardiovascular health.

Keywords: blood pressure; cardiovascular health; heart rate variability; laughter

1 Introduction

The use of humor as a therapeutic tool has grown significantly over the last decades. However, academic research on the effectiveness of this approach has taken up a much slower pace (Gelkopf 2011). Previous meta-analytical reviews about the positive effects of humor and laughter on mental health suggest that positive styles of

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humor (i.e., affiliative and self-enhancing) are positively correlated with mental health in young adults (Schneider et al., 2018). Furthermore, the use of positive humor in organizational settings also seems to be associated with improved health, work performance, decreased burnout and work withdrawal (Mesmer-Magnus et al. 2012). In romantic relationships, studies have reported that positive humor has a beneficial effect on the level of satisfaction with the relationship (Hall 2017) and is a central factor in interpersonal and social attraction (e.g., Bressler and Balshine 2006; Cann et al. 1997; McGee and Shevlin 2009; Murstein and Brust 1985).

However, despite its importance in central aspects of our social life, humor has been a particularly difficult concept to grasp, and hence to define and manipulate in the context of academic research. In particular, humor has been generally defined as a multi-faceted concept, which can include anything that a subject does or says that is perceived by others as being humorous, as well as the cognitive processes that contribute to the recognition and creation of the humorous stimuli and the emotional responses that people assign to them (Martin and Ford 2018).

Specifically, in terms of the emotional responses, mirth has been defined as “...*the distinctive emotion that is elicited by the perception of humor*” (Martin and Ford 2018; p. 6), and is typically expressed outwardly through laughter. This emotion has been characterized by subjective feelings of amusement, cheerfulness, and pleasure, and like other emotions, it has been associated with specific physiological changes (Carbelo and Jáuregui 2006; Martin and Ford 2018).

In this context, although humor, mirth and laughter are tightly interconnected, often happening together, they are separate phenomena (van der Wal and Kok 2019). In particular, laughter can be elicited as a response to humorous external events (i.e., spontaneous laughter) or by oneself voluntarily (i.e., simulated laughter; van der Wal and Kok 2019). In this context, little research has been conducted on the different effects that spontaneous and stimulated laughter can have on individuals' health, but a recent review suggested that simulated laughter seems to be more effective than spontaneous laughter at improving depressive symptoms (van der Wal and Kok 2019). Similarly, another review conducted by Mora-Ripoll (2011) concluded that both spontaneous and simulated laughter have positive impacts on health compared to control groups (both including waiting lists and no intervention, as well as active control groups who engaged in other activities, e.g., exercise therapy).

In terms of the effect of laughter on physical health, some authors have argued that it can have a positive effect on variables such as blood pressure (BP) regulation, SIgA (Secretory Immunoglobulin A) production (Ryu et al. 2015) and pain tolerance (Lapierre et al. 2019). However, the mechanisms through which humor and laughter exert this positive influence are still unclear (Martin 2002). Some argue that laughter has a *direct* influence on health; whereas others adopt the view that the effects of humor on health are mostly of an *indirect* nature.

Proponents of the first viewpoint, argue that laughter induces a set of physiological changes in various systems of the human body which can have positive effects on health (Martin 2002). Authors who argue that humor has an indirect effect on health, generally place the emphasis on humor as a trait or emotion (as opposed to focusing on laughter) as mediating or moderating variables that increase the beneficial effects associated with positive emotional states and serve as a buffer for the negative effects associated with stress (Martin 2002; Chinery 2007; Carbelo and Jáuregui 2006; Crawford and Caltabiano 2011).

As a result of the belief in the positive effects of laughter in physical and psychological health variables, many programs involving the use of humor or laughter as a therapeutic tool have emerged. Associations like the Laughter Association UK (<http://www.laughterassociation.com/>) or the Laughter Yoga International (<https://laughteryoga.org/>), promote the use of laughter-inducing interventions to improve health and well-being and train professionals to deliver these types of interventions. However, although the effectiveness of laughter-inducing interventions has been confirmed in improving conditions such as depression (van der Wal and Kok 2019), little is known regarding its effects on psychophysiological variables.

2 Laughter and the cardiovascular system

The link between laughter and the cardiovascular system has been, for a long time, a subject of interest for researchers in the medical and social sciences (Lefcourt et al. 1990). In this context, laughter seems to be integrated in a wider category of activities that involve the exercise of muscles crucial to the respiratory activity (e.g., coughing), and that display reciprocal influences in some aspects of cardiovascular functioning, such as BP regulation (Miller and Fry 2009).

The production of laughter is characterized by rapid contractions of the intercostal muscles, resulting in ample, quick, exhalations, which vocalization involves supra-laryngeal structures (Scott et al. 2014). In addition, the neural control of laughter involves two cortical systems that act on the midbrain and brainstem motor structures involved in the production of voluntary or learned (lateral premotor and motor areas) and involuntary (anterior cingulate and supplementary motor areas) vocalizations associated with laughter (Scott et al. 2014). Because laughing involves such a complex array of muscles and systems, vigorous laughing is believed to relax muscles, improve respiration and circulation, and decrease the production of stress-related hormones in the brain (Martin 2002).

Mirthful laughter has also been found to induce the release of β -endorphins, which due to its affinity for $\mu 3$ opiate receptors are thought to lead to a direct release

of NO (Nitric Oxide). NO, in turn, is known to affect smooth muscle relaxation, vessel dilation and might reduce vascular inflammation (Miller and Fry 2009).

3 Blood pressure

BP refers to the pressure measured within the arteries during the contraction of the heart (systolic blood pressure; SBP) and between heart contractions (diastolic blood pressure; DBP). BP can typically be measured using a standard sphygmomanometer, stethoscope, or a digital automated unit. Normal levels of BP tend to be between 90 and 120 for SBP and 60 and 80 for DBP in healthy adults (Pickering et al. 2004).

BP changes can be induced by a myriad of factors that are normal in our day-to-day lives. For instance, emotions directly impact biological pathways, such as the sympathetic nervous system and the hypothalamic–pituitary–adrenal axis, which in turn influence other biological processes involved in the regulation of BP (Trudel-Fitzgerald et al. 2016). In addition, as detailed above, the act of laughter involves the exercise of muscles directly involved in the regulation of the respiratory activity, which, as demonstrated by other similar behaviors (e.g., coughing; Criley et al. 1976) can impact cardiac activity in general, and BP in specific.

Positive emotions, in specific, and psychological well-being in general, are thought to be protective factors for cardiovascular disease, and to be positively associated with biological function and restorative health behaviors, and negatively associated with potentially harmful behaviors (e.g., smoking; Boehm and Kubzansky 2012). Previous reviews suggest that BP changes are associated with the experiencing of positive emotions (in specific, amusement), but the variability of the results reported for this variable does not allow us to stipulate a concise judgement on the nature of such changes (Kreibig 2010).

4 Heart rate variability

The human heart beats to a non-regular rhythm, due to the influence of the two branches of the autonomic nervous system on the heart (Shaffer and Ginsberg 2017). As such, heart rate variability (HRV), in general, is a measure of the oscillations in length of the intervals between heartbeats and can be a valuable indicator of the sympathetic and parasympathetic functions of the autonomic nervous system (Shaffer and Ginsberg 2017). The measurement of HRV can include frequency, time-domain, and non-linear indices. Frequency-domain indices allow the determination of the HRV four frequency bands (more specifically, high [HF], low [LF] and very-low [VLF] and ultra-low frequency [ULF] bands); whether time-

frequency domain indices allow for the quantification of the variability of inter-beats intervals (Shaffer and Ginsberg 2017). HF and LF can be calculated from short-term (2–5 min) or long-term recordings (24 h), are measured in absolute values of power (milliseconds squared) and vary according to autonomic modulations of heart period. The physiological explanation of VLF, on the other hand, is much less understood and thus its interpretation must be done with caution (Task Force of the European Society of Cardiology the North American Society of Pacing Electrophysiology 1996). Non-linear indices attempt to quantify the unpredictability of a series of inter-beat intervals. In addition, each of these indicators provides clues regarding the activity of different branches of the autonomic nervous system (Shaffer and Ginsberg 2017). For instance, HF is associated with parasympathetic activation given that it reflects the vagus nerve activity, whereas LF reflects sympathetic activity (Kim et al. 2018; Shaffer and Ginsberg 2017).

A previous review has shown that different emotions are associated with different patterns of autonomic system activation. In particular, amusement (manipulated in the studies included mostly by exposing participants to comedic material/films) is usually associated with increased “...*vagal control, vascular α -adrenergic, respiratory, and electrodermal activity, together with sympathetic cardiac β -adrenergic deactivation*...” (Kreibig 2010, p. 406).

Studies examining the physiological manifestation of amusement, as indexed by heartrate (HR), have shown inconsistent results, with some studies reporting an increase, others reporting a decrease, and others reporting no change in HR as a result of exposure to amusement-inducing material (Kreibig 2010). However, a previous review suggested an increase in HRV, as indicated by time-domain measures, such as SDNN (standard deviation of the inter-beat-intervals of normal sinus beats) and MSD (mean difference between successive RR intervals; Kreibig 2010), as a common response pattern to amusement-inducing stimuli. Frequency-domain measures, such as LF/HF, tended to remain unchanged in the studies included in that review (Kreibig 2010). CO (cardiac output), which is the product of heart rate and stroke volume, decreased after exposure to amusement-inducing stimuli (Kreibig 2010).

5 Positive psychology interventions and the present research

Positive psychology is a subfield of psychology that is concerned with identifying, developing and evaluating interventions aimed at improving well-being and health (Carr et al. 2020; Seligman and Csikszentmihalyi 2014). Positive psychology

interventions can impact well-being through diverse pathways, including enhancing relationships, promoting meaning and purpose and promoting positive and enriching experiences (Carr et al. 2020; Seligman and Csikszentmihalyi 2014). In this context, humorous interventions have been shown to have a small to medium positive effect on well-being and reducing depression symptoms, and a large effect on increasing character strengths and reducing anxiety and stress (Carr et al. 2020).

Congruently, it has also been theorized that intense emotions, despite their content, lead to activation of the sympathetic nervous system (Bennet and Lengacher 2008). In a study conducted by Averill (1956), the author observed that while sad and humorous stimuli led to an increase in galvanic skin responses, only sad stimuli were associated with increased blood pressure, suggesting that humor could help buffer some of the negative effects associated with sympathetic intervention.

Other theories have also, more generally, stressed the beneficial impact of positive emotions on physical health. In this context, positive emotions are thought to improve health by reducing the duration of negative emotional states, which due to their association with heightened and prolonged cardiovascular activation, have been implicated in the emergence of heart disease (Blascovich and Katkin 1993; Fredrickson et al. 2000; Frederickson 2011).

Similarly, the *broaden-and-built* theory argues that better recovery is a central pathway connecting positive affect to improved well-being (Fredrickson and Joiner 2002). In this context, studies comparing the amount of time required to return to resting levels of cardiovascular function between participants who smiled during stressful situations and non-smiling participants, observed that smiling participants recover more quickly than their non-smiling counterparts (Fredrickson and Levenson 1998), even when their smile is simulated (Kraft and Pressman 2012).

Previous reviews about the effects of positive emotions on physical health have supported theoretical claims about their beneficial effects on different variables, including immune system response (Howell et al. 2007) and inflammation (Steptoe et al. 2008), being associated with an overall decrease in mortality (Chida and Steptoe 2008). This beneficial effect of positive emotions on physical health is thought to be explained by people's own perceptions of their social relationships, which lead to improved vagal tone, and contribute to the creation of an upward-spiral dynamic (Kok et al. 2013).

However, there are still few reviews that have been conducted to investigate the specific effects of humor and laughter on health variables, which is important to determine given the growing implementation of laughter or humor-based therapies in clinical settings, their wide appeal to the lay public (Bennet and Lengacher 2008) and the aforementioned claims regarding their effectiveness in improving physical health. With this review and meta-analysis, we seek to

contribute towards closing that gap by investigating the effects of laughter on BP and HRV.

6 Goals

The objective of this review is to analyze the effects of laughter-inducing interventions (LII) on BP regulation and HRV at two levels: (a) intraindividual (*pre-post comparisons*) and (b) interindividual (*active vs. control group comparisons*). In interindividual comparisons, we seek to compare LII to active (e.g., writing exercises) and passive control groups. In addition, we seek to identify and summarize the results of *longitudinal studies* involving the effects of laughter or humor in the cardiovascular system and general health.

7 Method

7.1 Eligibility criteria

Studies published until August 2020 examining the effects of LII (for a review on different types of LII, see Ruch and McGhee 2014) on BP and HRV, including pre-post comparisons, controlled trials, and longitudinal designs that spanned for more than one-year, were eligible. These interventions can include any type of laughter-inducing intervention, including both interventions involving simulated laughter (i.e., non-humorous, e.g., laughter yoga) or spontaneous laughter (i.e., humorous, e.g., clown interventions).

Studies were included if they provided enough information regarding the BP levels indifferent conditions, or for pre-post assessments for at least one type of BP measurement (systolic or diastolic). If such information was not present a qualitative summary of the results was presented instead. Given the wide variability of parameters that can be employed to assess HRV, we provided a qualitative summary of the results of the studies included for this variable. For both outcomes, if a sufficient number of homogeneous studies was found, a statistical meta-analysis was conducted to quantify the effect sizes.

Peer-reviewed articles presenting an abstract and written in English were preferred, but for reasons of achieving wider inclusivity of non-Western literature, translations of relevant articles were procured when possible. Approved theses (master's degree or PhD) were also included in the review. No other exclusion criteria were defined.

7.2 Data collection, search procedure, and study selection

Studies were identified using appropriate digital libraries in medical and social sciences. The databases searched were PubMed, Web of Science, ScienceDirect, and Scopus. To reduce the chance of publication bias, parallel searches were conducted in thesis repositories (OTAD; Open Access Thesis and Dissertations) and other platforms likely to host grey literature or preprint manuscripts (Open Science Framework; arXiv), as well as in other scientific repositories (Academic Google, Microsoft Academic, ResearchGate). The search was last conducted in February 2021, and included papers published between January 2000 and August 2020.

The search terms used included the following keywords (humor OR laughter) AND (blood pressure OR heart rate variability) anywhere on the title, abstract, or keywords of a paper. At this stage, we purposefully did not narrow the search by including more restrictive search terms to avoid missing potentially relevant papers. The study selection procedure is detailed in Figure 1.

After achieving a first selection of the relevant papers, the reference section of each was thoroughly analyzed in search of other potential papers that could fit our inclusion criteria. This process was repeated in the newly identified papers until all new references were exhausted, and the search process was terminated.

The information retrieved from the selected papers included both extrinsic and intrinsic characteristics. In terms of extrinsic characteristics, we collected information regarding the (1) title, (2) publication year, (3) author list, (4) country of origin (as inferred from the affiliation of the first author), (5) disclosure of funding

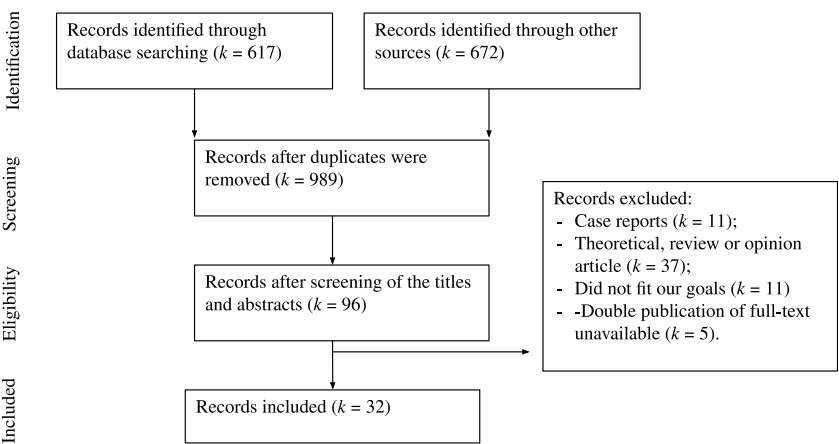


Figure 1: PRISMA diagram detailing the study screening and selection process.

sources, and (6) conflict of interests. For intrinsic information, we collected data regarding (7) sample size, (8) demographic characteristics of the sample, (9) type of intervention (simulated vs. spontaneous) and implementation (frequency, number of sessions, duration, activities included), (10) study design, (11) BP levels, (12) type of HRV indicators measure, and (13) summary of the main findings of each study.

The information extraction (and the initial screening of records) was conducted by the first author and by an external examiner, who also contributed to the quality of the appraisal process. Both reviewers worked independently and solved disagreements by discussing them during joint meetings. A third reviewer and the main author independently conducted the risk of bias appraisal and the same disagreement resolution method was adopted.

When translation of articles was necessary (in our case, for articles written in Iranian and South Korean), two native speakers of those languages were asked to assist independently in the translation. Their translations were then read and integrated by the first author and doubts regarding the content of the translation were answered in joint meetings.

7.3 Extrinsic characteristics and quality appraisal

The 32 studies included in this review originated from varied geographic backgrounds, with Japan ($k = 6$; Hayashi et al. 2016; Ikeda et al. 2020; Nasir et al. 2005; Sakurada et al. 2019; Sakuragi et al. 2002; Sugawara et al. 2010); the USA ($k = 4$; Berger et al. 2014; Boone et al. 2000; Dolgoff-Kaspar et al. 2012; Rizzolo et al. 2009); India ($k = 4$; Nagoor and Dudekula 2015; Priya 2016; Rampalliwar et al. 2016; Salomi et al. 2018), South Korea ($k = 2$; Yu and Kim 2009; Yun et al. 2015), Iran ($k = 2$; Eshg et al. 2017; Jalali et al. 2008), Taiwan ($k = 2$; Chang et al. 2013; Wang et al. 2020), and the UK ($k = 2$, Harrison et al. 2000; Kanji et al. 2006) being the most predominant contributors. The other studies originated from Finland (Kerkkanen et al. 2004), Turkey (Hasan and Saritas 2020), Brazil (Alcântara et al. 2016), Slovenia (Krebs et al. 2014), Australia (Ellis et al. 2017), Spain (Ruiz-Padial and Ibáñez-Molina 2018), Indonesia (Kasenda and Jael 2016), Austria (Lackner et al. 2014), Greece (Vlachopoulos et al. 2009), and New Zealand (Law et al. 2018; all $k = 1$). With the exception of one thesis (Priya 2016), all the other papers were published in peer-reviewed journals.

Quality appraisal was conducted using the quality assessment tool for quantitative studies developed by the Effective Public Health Practice Project (2012). Because treatment allocation was obvious (i.e., participants allocated to an experimental condition involving a laughter activity would be very aware of the manipulation and dependent variables), due to the nature of the intervention and

measures collected, this item of quality assessment was not coded (see van der Wal and Kok 2019).

Overall, most of the studies included were evaluated as being weak ($k = 16$). The main factors contributing to this evaluation were related to selection bias (namely the lack of sample representativeness and the lack of information regarding the percentage of individuals that agreed to participate in the study), the lack of information about possible relevant confounder variables and intervention integrity (namely, lack of control or information about the consistency of the interventions, and lack of control about possible co-interventions or activities that might have influenced the results). This latter factor, intervention integrity, was also present in other studies which were classified as providing evidence of moderate strength ($k = 10$). However, these studies were evaluated as presenting more information regarding possible selection biases, confounders, and consistency of the applied intervention.

The remaining studies were evaluated as providing strong evidence ($k = 6$) due to the overall quality of the study design, statistical analysis and quality of the evaluation, and reporting of the study procedure and possible confounder variables.

Regarding the quality assessment of studies per variable, we found that 14 studies involving BP measurements were evaluated as providing weak evidence; 10 were evaluated as providing moderate strength evidence and the remaining 6 were evaluated as providing strong evidence. Of the studies included for HRV, we found that 2 provided strong evidence and 2 provided moderate strength evidence.¹

In terms of the laughter-inducing activities, we found three main clusters. The most predominant way to induce laughter in the studies included was through the presentation of humorous films or video clips ($k = 13$). These videos could be short clips of stand-up comedians performing, popular late-night programs, movies, or short compilations of humorous clips.

The second most prominent cluster of laughter-inducing activities included studies that analyzed laughter therapy ($k = 10$) and laughter yoga ($k = 2$). These activities generally include breathing exercises and the production of simulated laughter; and might or might not include other relaxation exercises that are performed concomitantly.

Third, some of the studies included induced laughter through exposure to clown interventions, and other silly activities (e.g., dressing up in costumes, putting on funny make-up; $k = 3$). One study induced laughter through giving laughter-inducing commands to participants.

¹ Note that the remaining three studies for HRV, also measured changes in BP, and as such, these studies' quality assessment scores were measured together with the other BP studies.

Approximately half of the non-longitudinal studies employed multiple-sessions of laughter-inducing activities ($k = 15$); whereas the other half included a single session. The average number of sessions for the studies involving multiple-session interventions was 8, with the average total duration (sum of the duration of each individual session) of said intervention being 339 min ($SD = 298.90$; ranging from 60 to 1,040 min).

For the studies involving single-session interventions, the average duration of the intervention was approximately 23 min ($SD = 22.37$; ranging from 3 to 71 min).

7.4 Risk of bias

According to recommendations, risk of bias was assessed using ROBINS-I (Sterne et al. 2016) for non-randomized intervention studies and ROB 2 (Sterne et al. 2019) for randomized intervention trials. Visualizations of the outcomes of the risk of bias assessment were produced using the robvis tool (McGuinness and Higgins 2017) and are presented in Figures 2 and 3.

8 Data analysis

8.1 Blood pressure

We included in this review 28 studies involving BP and cardiovascular health in general. Eighteen studies employed pre-post comparisons levels of BP, seven studies involved controlled trials, and four longitudinal studies explored the effects of frequency of laughter and sense of humor in BP or overall cardiovascular health. The remaining articles ($k = 4$) analyzed BP changes related to LII, however, because they did not present the mean BP values (or presented it in graphical form only), we can only provide a qualitative summary of these results.² These four articles used a repeated measures design (Dolgoft-Kaspar et al. 2012; Harrison et al. 2000; Lackner et al. 2014; Vlachopoulos et al. 2009).

Congruently with our goals, data analysis of the articles included in this review will be organized according to the type of comparisons conducted within each paper (pre-post comparison, active vs. control and longitudinal). Some overlap of the articles included in terms of the type of comparison group employed was

² The corresponding authors of each of these studies were contacted via e-mail and requested to provide the data regarding the BP measurements, however, to this date, we have not received an answer.

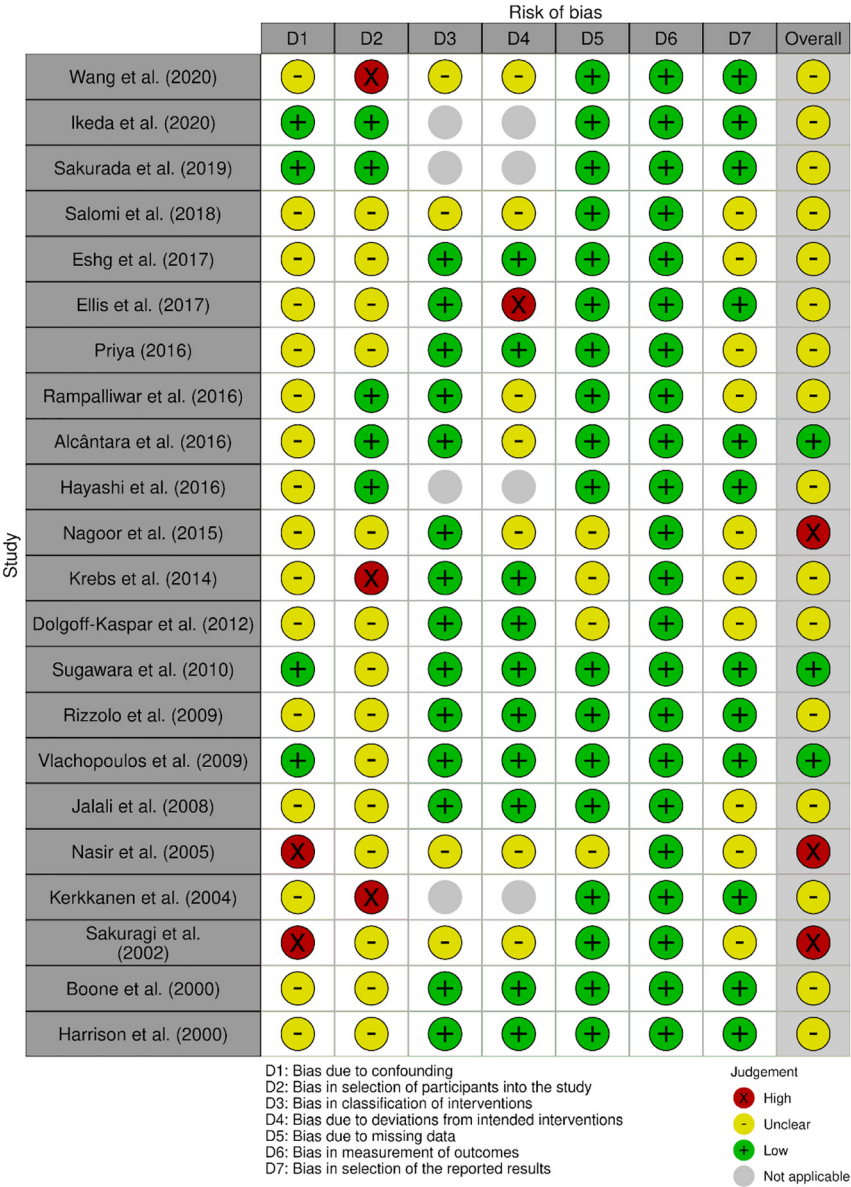


Figure 2: Risk of bias assessment for pre-post and longitudinal comparisons studies using ROBINS-I.



Figure 3: Risk of bias assessment for randomized or controlled trials using RoB 2.

observed, with some studies reporting both pre–post and active versus control group comparisons ($k = 5$; Berger et al. 2014; Chang et al. 2013; Hasan and Saritas 2020; Kanji et al. 2006; Yun et al. 2015), resulting in a total sum of 28 individual articles included.

Data analysis of the BP scores for the studies including pre–post comparisons will be merely descriptive. Although methods for calculating effect sizes in studies involving dependent groups exist (e.g., Morris and DeShon 2002), its interpretability and susceptibility to bias has been noted recently (Cuijpers et al. 2017). In addition, the majority of the studies included in this category did not present correlation values between pre–post measures, which would be necessary to calculate effect sizes, and no reliable estimates for this correlation are present in previous literature, to the best of our knowledge. Furthermore, this type of comparison is potentially subject to a number of known effects, such as regression to the mean and the Hawthorne effect. The effects of regression to the mean have been specifically studied in regard to BP measurements, demonstrating that baseline measurements of BP tend to decrease in comparison to follow-up measures (Moore et al. 2019). This potential effect of potential bias is aggravated in this case by a lack and overall inconsistency of the demographic and health-related characteristics reported for participants in each study, that might affect the full comprehensibility of the results reported.

Two meta-analyses were conducted for the effects of LII: one for SBP and another for DBP. In all studies, BP was measured in units of millimeters of mercury (mmHg). Assuming an overall effect size of 0.5, and an average number of 25 participants per condition (experimental and control) and the nine individual comparison groups included, the estimated statistical power for the meta-analysis varied between 0.99 (low heterogeneity) to 0.75 (high heterogeneity).

Hedge's g was calculated to compare the standardized effect sizes between active and control groups, considering the small sample sizes observed in the majority of the studies included in this category. Sub-group analysis was not conducted due to the small number of studies included in the meta-analysis, and the relatively high level of heterogeneity observed (as measured by I^2). The common interpretation of heterogeneity scores as provided by I^2 is that higher values of this statistic indicate higher levels of within-subgroup heterogeneity.

According to statistical recommendations, Egger's test was used to assess publication bias, instead of the more common fail-safe N method (Higgins et al. 2019). Analyses were conducted using Jeffreys's Amazing Statistics Program (JASP) software (version 0.12.2). In accordance with common practice, a p value inferior to 0.05 will be considered evidence to reject the null hypothesis.

8.2 Heart rate variability

Seven articles involving the analysis of HRV changes associated with LII were identified (Chang et al. 2013; Dolgoff-Kaspar et al. 2012; Lackner et al. 2014; Law et al. 2018; Ruiz-Padial & Ibáñez-Molina, 2018; Sakuraki et al. 2002; Wang et al. 2020).

Some of the studies included for this variable also presented measurements of BP. Therefore, there is some overlap between the studies already included in the section above. The results for HRV were considered separately from the results of BP measures. The studies included used different measures of time-domain (rMSSD and Standard Deviation of the normal-to-normal intervals, SDNN) and of frequency-domain HRV (LF/HF, LF, HF), with the most frequently reported being rMSSD ($k = 4$), LF/HF, LF or HF ($k = 4$), and SDN ($k = 3$). Due to the variability in the measures reported in each study, and the lack of consistency regarding the measures reported in the studies included as whole, a statistical analysis of the effect size of the reported effects was not possible. Instead, the results for these studies will be summarized qualitatively by analyzing the main conclusions of each study.

9 Results

9.1 Blood pressure

9.1.1 Pre–post comparisons

A summary of the studies included for BP is presented in Table 1.

A net reduction of 3.97 and 3.14% in SBP and DBP, respectively, was observed when comparing pre-post BP measurements for individuals who participated in LII. When excluding the studies involving patients with hypertension ($k = 2$, remaining $n = 648$), a reduction of 3.97% and of 2.08% in SBP and DBP, respectively, was observed between pre ($MSBP = 121.82$, $MDBP = 75.52$) and post ($MDBP = 118.21$, $MDBP = 73.95$) measurements. In individuals with hypertension ($n = 85$), SBP decreased by 10.94% between pre-post measurements ($MPre = 148.21$; $MPost = 132.00$), whereas DBP decreased by 10.29% in pre-post measurements ($MPre = 90.61$, $MPost = 81.29$).

When considering only the studies for which no diseases were reported ($k = 10$; $n = 434$), the results suggest a 3.70% and a 3.66% drop in SBP and DBP, respectively, between pre ($MSBP = 122.04$, $MDBP = 77.15$) and post ($MSBP = 117.52$, $MDBP = 74.33$) measurements. In children (<18 years old; $k = 3$; $n = 118$), participating in LII was associated to a reduction of 0.51% in SBP ($MPre = 115.38$, $MPost = 114.77$); and to an increase of 4.62% in DBP ($MPre = 70.84$, $MPost = 74.27$).

In studies involving simulated laughter ($k = 7$; $n = 393$), the overall reduction in SBP ($MPre = 130.81$, $MPost = 123.15$) and DBP ($MPre = 83.65$, $MPost = 75.34$), corresponded to 5.86 and 9.94% decrease. In studies analyzing the effects of spontaneous laughter ($k = 11$, $n = 340$), the corresponding reduction observed was 3.54% for SBP ($MPre = 123.47$, $MPost = 119.10$). For DBP, an increase of 0.39% was observed ($MPre = 75.05$, $MPost = 75.34$).

In studies involving multiple-session interventions, the overall decrease in SBP was 5.94% ($MPre = 130.09$, $MPost = 122.36$), and of 5.19% for DBP ($MPre = 80.87$, $MPost = 76.67$).

For single session-interventions, the corresponding reduction was of 0.95% for SBP ($MPre = 116.02$, $MPost = 114.92$); and of 0.32% for DBP ($MPre = 71.95$, $MPost = 71.72$).

The four studies that did not report BP values, or did so in graphical form, presented inconsistent results, with three not reporting changes in DBP, two not reporting changes in SBP and one reporting increases in SBP ranging from 3 to 23% after the intervention.

Table 1: Comparison of blood pressure levels using repeated measures after a laughter inducing intervention and between intervention groups and control groups. A summary of the results of studies that did not present specific blood pressure levels is presented at the end of the table.

Study		Demographic characteristics			Intervention characteristics			
		Sample size	Age (<i>M</i> ± <i>SD</i>)	Number of female participants	Type of laughter	Intervention	Number of sessions	Duration of intervention (min)
Hypertension	Jemmi Priya (2016)	50	n/a ¹	25	Simulated	Laughter therapy	4	80
	Jalali et al. (2008)**	35	55.1 ± 10.7	30	Spontaneous	Watched comedy videos	8	720
Chronic renal failure	Eshg et al. (2017)**	40	56 ± n/a	26	Spontaneous	Laughter therapy	16	480
Cancer	Hasan and Saritas (2020)	88	E = 61.06 ± 13.32; C = 63.38 ± 13.87	41	Spontaneous	Watched comedy videos	1	10
Diabetes	Nasir et al. (2005)	18	61.4 ± 1.4	3	Spontaneous	Watched comedy videos	26	1,040
No reported diseases	Salomi et al. (2018)	100	n/a ²	35	Simulated	Laughter therapy	10	n/a
	Kasenda and Jael (2016)	40	n/a	n/a	Simulated	Laughter therapy	4	100
	Rampalliwar et al. (2016)	40	n/a ³	n/a	Simulated	Laughter Yoga	6	360
	Yun et al. (2015) ^b	50	n/a ⁴	46	Spontaneous	Clown intervention	1	60
	Nagoor and Dudekula (2015)	100	n/a ⁵	35	Simulated	Laughter therapy	10	n/a
	Berger et al. (2014) ^b	42	37.6 ± 7.3	40	Spontaneous	Children were given toys and the parents and children were given colorful costumes	1	71
	Krebs et al. (2014)	41	52.5 ± n/a	n/a	Simulated	Laughter therapy	10	600
	Chang et al. (2013)	67	n/a ⁶	33	Simulated	Laughter therapy	8	360
	Sugawara et al. (2010)	17	26 ± 1	5	Spontaneous	Watched comedy videos	1	30
	Rizzolo et al. (2009)	22	26 ± n/a	19	Spontaneous	Watched comedy videos	3	90
Mixed	Kanji et al. (2006)	61	n/a ⁷	57	Spontaneous	Participants were given laughter-inducing commands	8	160
	Boone et al. (2000)	8	22 ± 0.5	4	Spontaneous	Watched comedy videos	1	5
	Ellis et al. (2017)	28	84 ± n/a	23	Simulated	Laughter yoga	6	180
	Alcântara et al. (2016)	41	7.6 ± 2.7	15	Spontaneous	Comedic performances, magic tricks, juggling, singing and soap bubbles	1	20
	Yu and Kim (2009)	36	E = 20.9 ± 1.2; C = 21.7 ± 1.5	0	Simulated	Laughter therapy	3	180
	Berger et al. (2014) ^a	43	10.20 ± 4.00	23	Spontaneous	Children were given toys and the parents and children were given colorful costumes	1	71
	Yun et al. (2015) ^a	50	n/a ⁸	46	Spontaneous	Clown intervention	1	60
Mixed	Dolgoﬀ-Kaspar et al. (2012)	3	59.83 ± 7.05	n/a	Simulated	Laughter therapy	3	60
No reported disease	Lackner et al. (2014)	48	21.00 ± n/a	48	Spontaneous	Watched comedy videos	1	3
	Vlachopoulos et al. (2009)	18	26.9 ± 2.6	10	Spontaneous	Watched comedy videos	1	30
	Harrison et al. (2000)	30	n/a ⁹	15	Spontaneous	Watched comedy videos	1	10

Table 1: (continued)

Study		Intervention				Control			
		Pre intervention		Post intervention		Pre intervention		Post intervention	
		Systolic (M ± SD)	Diastolic (M ± SD)	Systolic (M ± SD)	Diastolic (M ± SD)	Systolic (M ± SD)	Diastolic (M ± SD)	Systolic (M ± SD)	Diastolic (M ± SD)
Hypertension	Jemmi Priya (2016)	144.52 ± 5.37	94.52 ± 2.93	126.8 ± 5.17	82.88 ± 3.13				
	Jalali et al. (2008)**	151.9 ± 6.3	86.7 ± 11	137.2 ± 4.2	79.7 ± 9.5				
Chronic renal failure	Eshg et al. (2017)**	136 ± 18.6	80.8 ± 7.3	119 ± 18.8	74.3 ± 7.8				
Cancer	Hasan and Saritas (2020)	132.25 ± 18.96	83.61 ± 14.04	128.15 ± 15.57	79.77 ± 11.63	128.63 ± 16.07	80.88 ± 9.93	127.47 ± 14.38	78.97 ± 9.24
Diabetes	Nasir et al. (2005)	129 ± 9	76 ± 6	128 ± 9	73 ± 8				
No reported diseases	Salomi et al. (2018)	126.37 ± 6.09	79.49 ± 8.29	118.67 ± 5.81	72.96 ± 7.94				
	Kasenda and Jael (2016)	122.5 ± 9.25	80.75 ± 7.99	114.75 ± 7.69	77.75 ± 7.16	n/a	81.5 ± 7.45	n/a	82.25 ± 7.34
	Rampalliwar et al. (2016)	124.4 ± 5.25	82.44 ± 2.96	122.9 ± 4.29	76.78 ± 3.57				
	Yun et al. (2015) ^b	114.00 ± 8.79	75.13 ± 7.74	112.17 ± 6.51	72.83 ± 7.19	115.30 ± 8.97	71.74 ± 8.11	118.37 ± 9.28	75.75 ± 5.83
	Nagoor and Dudekula (2015)	125.37 ± 6.09	79.49 ± 8.29	119.7 ± 5.62	73.56 ± 8.73				
	Berger et al. (2014) ^b	126.3 ± 11.7	81.3 ± 8.7	122.7 ± 11.4	80.9 ± 8.7	125.2 ± 18.4	79.3 ± 12.6	122.9 ± 16.2	79.2 ± 10.9
	Krebs et al. (2014)	133.15 ± 18.94	87.75 ± 12.86	120.65 ± 14.79	81.42 ± 10.9				
	Chang et al. (2013)	124.34 ± 24.25	78.22 ± 11.1	119.91 ± 14.03	80.22 ± 8.21	112.87 ± 11.97	78.94 ± 8.14	113.19 ± 17.55	76.19 ± 12.29
	Sugawara et al. (2010)	112 ± 2	59 ± 2	110 ± 2	58 ± 2				
	Rizzolo et al. (2009)	113.95 ± 10.03	70.05 ± 7.72	110.45 ± 12.08	65.09 ± 8.83				
Mixed	Kanji et al. (2006)	116.5 ± 11.1	75.8 ± 11.6	110.2 ± 12.2	74.4 ± 11.7	110.1 ± 15.5	73.8 ± 12.3	112.6 ± 12.9	73.7 ± 10.2
	Boone et al. (2000)	118 ± 4	78 ± 6	120 ± 6	80 ± 6				
	Ellis et al. (2017)	137.5 ± 21.4	n/a	133.4 ± 18.1	n/a				
	Alcántara et al. (2016)	112.2 ± 13	71 ± 11.7	116.7 ± 14.9	75 ± 16.7				
	Yu and Kim (2009)	n/a	n/a	132 ± 17.85	84.71 ± 10.2	n/a	n/a	121.11 ± 11.49	77.37 ± 10.12
	Berger et al. (2014) ^a	109.6 ± 12.3	63.3 ± 9.1	107.7 ± 9.4	67.6 ± 8.4	115.5 ± 14.7	68.45 ± 11	108.1 ± 12.7	63.3 ± 9.2
	Yun et al. (2015) ^a	103.78 ± 12.68	64.22 ± 10.99	101.91 ± 10.69	59.62 ± 12.75	107.00 ± 9.54	61.78 ± 12.09	108.52 ± 9.37	60.56 ± 10.09
	Summary of results								
Mixed	Dolgoﬀ-Kaspar et al. (2012)	Participants experienced an increase in systolic blood pressure after the intervention, ranging from 3 to 23%.							
No reported disease	Lackner et al. (2014)	No significant main effects were observed in blood pressure levels.							
	Vlachopoulos et al. (2009)	Watching a comedic film did not induce changes in systolic or diastolic blood pressure.							
	Harrison et al. (2000)	No differences were observed in systolic blood pressure after watching a humorous video. Diastolic blood pressure increased after viewing the humorous film.							

When information regarding a specific variable was not found or provided in the original paper, we denoted the lack of it using “n/a”. Studies with superscript numbers in the age column did not present participant’s mean age or standard deviation. If an age range or any other information relevant to age determination was presented, that information is presented below. For studies involving a control group, when separate means and standard deviations values are presented for the experimental (E) and control (C), these are also presented in the table separately. Studies with superscript letters ^(a,b) denote papers in which the pre-post comparisons of the effects of laughter-inducing interventions were conducted in more than one independent group. The studies marked with asterisks were translated from their original Iranian and South Korean with the kind help of native speakers. ¹Participant’s ages ranged between 35 and 45 years old, with 32% of participants being between 35 and 38, 34% being between 39 and 42, and 34% being between 43 and 45 years old. ²Participants’ ages ranged between 18 and 70 years old. ³Participants’ ages ranged between 18 and 23 years old. ⁴Participants’ ages ranged between 25 and 45 years old. ⁵Participants’ ages ranged between 18 and 69 years old. ⁶Participants’ are reported to be school children. ⁷Participants’ ages ranged between 19 and 49 years old. ⁸Participants’ ages ranged between 3 and 11 years old. ⁹Age statistics are provided separately for men ($M = 21.07$; $SD = 1.83$) and women ($M = 20.93$; $SD = 0.96$).

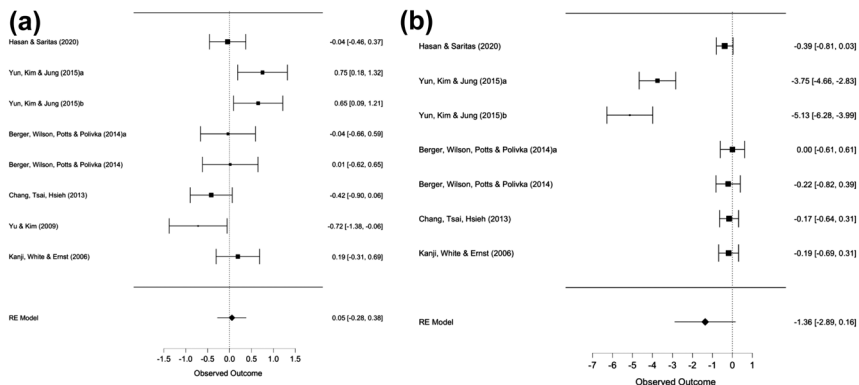


Figure 4: Forest plot of the studies included for (a) systolic and (b) diastolic blood pressure.

9.1.2 Active versus control groups comparisons

The pooled effect size of LII for SBP was 0.05 ($z = 0.32$, $p = 0.75$, $I^2 = 65.85$) and -1.36 for DBP ($z = -1.75$; $p = 0.08$, $I^2 = 47.41$; see Figure 4).

Significant publication bias was found for findings on SBP, as evidenced by the Egger's test ($z = -5.99$; $p < 0.001$); however, no significant risk was found for the findings involving SBP ($z = -0.19$; $p = 0.85$).

9.1.3 Longitudinal studies

We identified four longitudinal studies evaluating the link between laughter and humor and BP. The first study was published in 2004 by Kerkkanen and colleagues, and described a longitudinal prospective study involving 34 Finnish police officers, with an initial collection of data taking place in 1995 and with a follow-up in 1998. The authors were interested in evaluating the association between sense of humor (as measured by the Multidimensional Sense of Humor Scale; MSHS; Thorson and Powell 1993) and a series of physical health and workplace wellbeing measures (including cardiovascular health, and in particular, BP). The MSHS measures sense of humor in terms of (a) humor generation, (b) amusing humor, and (c) coping humor. The authors found no correlation between sense of humor and BP (systolic and diastolic) in either the data collected in 1995 or in 1998. Furthermore, they found that sense of humor was not a good predictor of BP changes between those two periods of time. Across the different analysis conducted for these two variables, the mean absolute correlation value observed was of 0.08 for SBP and of 0.11 for DBP.

The second longitudinal study (Ikeda et al. 2020) analyzed the link between frequency of laughter and BP in a sample of 1,441 Japanese individuals without a history of cardiovascular diseases, between 2010 and 2014 (with yearly follow-ups). Ikeda et al. (2020) found no overall difference in BP according to the frequency of laughter at baseline measurements; and no overall longitudinal differences in BP in women. In middle-aged men, infrequent laughter (1–3 times a month, or almost never) was associated with increased SBP and DBP over the 4-year period, when compared to men who reported laughing frequently (1–5 days a week, or almost every day), and this effect was “...confined to current drinkers...” (p. 5) and to men who were not on hypertensive medication. In this study, only 12.99% ($n = 72$) of men and 8.05% ($n = 116$) of the total sample reported laughing infrequently.

A third study ($n = 20,934$) found that, even after controlling for risk and other factors (e.g. hyperlipidemia, hypertension, depression, body mass index), the prevalence of heart diseases was superior among participants who reported laughing infrequently versus those who reported laughing frequently (Hayashi et al. 2016); however, the causal direction of this relation is unclear.

Fourthly, in the study by Sakurada et al. (2019; $n = 17,152$) it was found that the incidence of cardiovascular disease (as well as mortality) was significantly higher in individuals who reported low frequency of laughter.

9.2 Heart rate variability

9.2.1 Pre-post comparisons

A summary of the studies included for HRV is presented in Table 2. All of the studies included for HRV included pre-post comparisons. Overall, the studies presented mixed results with approximately half of the studies included ($k = 3$) reporting no significant changes in measures of HRV between pre-post measurements. The other studies present incoherent results, with some reporting an increase in rMSSD (Dolgoeff-Kaspar et al. 2012), and others reporting a decrease (Wang et al. 2020). In the majority of the studies that investigated changes in SDNN associated with LII, it was found that the value of this variable increased (Dolgoeff-Kaspar et al. 2012; Lackner et al. 2014; Wang et al. 2020). However, in the study by Lackner et al. (2014), this variable only increased for participants who rated their amusement with the comedic material shown as being high.

Taken together, the studies that analyzed changes in rMSSD, and from which we could retrieve numerical information ($k = 5$) indicate an average increase of

Table 2: Summary of studies analyzing the effects of laughter-inducing interventions in HRV.

Study	Demographic characteristics			Intervention characteristics			Results	
	Sample Size	Age (<i>M</i> ± <i>SD</i>)	Number of female participants	Type of laughter	Intervention	Number of sessions	Duration of intervention (min)	Summary
Mixed	3	59.83 ± 7.05	n/a	Simulated	Laughter therapy	3	60	rMSSD; SDNN Prior to the intervention, participants presented rMSSD and SDNN values below normal. After participation, participants presented rMSSD and SDNN values within or close to the normal range.
No reported disease	48	42.15 ± 20.31	21	Simulated	Laughter therapy	1	30	LF/HF; RMSSD; PSI; SDNN; TP Regular practitioners presented higher SDNN after a single session.
	52	34.00 ± 10.13	31	Simulated	Laughter therapy	1	30	LF/HF; RMSSD; PSI; SDNN; TP Participants who irregularly participated in a laughter therapy program presented lower RMSSD after the intervention.
	72	24.15 ± 1	24	Spontaneous & Simulated	Watched comedy videos/ Instructed to generate laughter	1	6	rMSSD; InrMSSD There were no sig. changes either in rMSSD or InrMSSD associated with spontaneous laughter. Simulated laughter led to a decrease in rMSSD.

Table 2: (continued)

Study	Demographic characteristics			Intervention characteristics			Results Summary
	Sample Size	Age (<i>M</i> ± <i>SD</i>)	Number of female participants	Type of laughter	Intervention	Number of sessions	Type of indicators used
Ruiz-Padial & Ibáñez-Molina (2018)	21	20.8 ± 1.4	7	Spontaneous	Watched comedy videos	1	5 DFA When exposed to a comedic video, participants presented higher HRV than when watching a neutral video or a fear-inducing video.
Lackner, Weiss, Hinghofer-Szalkay & Papousek (2014)	48	21.00 ± 2.7	48	Spontaneous	Watched comedy videos	1	3 SDNN; rMSSD; SD2/SD1; LF; HF; LF/HF; TOT Viewing humorous clips was associated with increased SDNN, SD2/SD1, TOT, LF, LF/HF, but only when the subjective amusement reported by participants was high.
Chang, Tsai & Hsieh (2013)	67	n/a ¹	33	Simulated	Laughter therapy	8	360 HRV; LF; HF; LF/HF No changes were observed for the experimental group.
Sakuragi, Sugiyama & Takeuchi (2002)	10	n/a ²	10	Spontaneous	Watched comedy videos	1	50 LF; HF; LF/HF Although there were changes in HRV during laughter, no sig. differences in this variable were found when comparing pre-post measurements.

¹Participants are reported to be school children. ²Participant's ages ranged between 20 and 22 years old.

0.75% in this variable between pre-post measurements. For SDNN, an increase of 7.01% was reported ($k = 2$) and for LF/HF a net increase of 7.42% was found ($k = 3$).

10 Discussion

The view that laughter has positive effects in health is a popular one, both among academics and the general public alike. However, the relationship between these two variables is not as straightforward as it might appear at first glance. Previous meta-analyses have suggested that laughter has positive effects in some factors related to mental health, such as anxiety, depression, and perceived stress (van der Wal and Kok 2019). However, when it comes to the effects of laughter or humor in physiological variables, the evidence becomes scarcer.

In this review, we found that the overall decrease in BP observed in individuals after participating in LII was of approximately 4.5% for SBP and of 4% for DBP. The highest percentage decrease in BP in the pre–post measurements was observed in patients with hypertension, corresponding to approximately 11 and 10% in SBP and DBP, respectively.

Congruent with what was reported in the meta-analysis conducted by van der Wal and Kok (2019), interventions using non-humorous laughter were reported to be associated with higher relative decreases in BP, when compared to humorous laughter, for the studies included in this review. However, when we consider studies in which the authors employed a control group, the effect of LII appeared to be non-significant.

In addition, although longitudinal studies analyzing BP dealt with different aspects of humor (laughter and sense of humor), taken together, they seem to provide some evidence in favor of the impact of laughter and humor on BP and cardiovascular health. However, these studies were not without limitations that might have impacted the results observed.

For instance, the study involving sense of humor not only involved a small sample size ($n = 34$) but also failed to control for other health and lifestyle variables that might impact cardiovascular health and included only men (Kerkanen et al. 2004). Although they collected information regarding Body Mass Index (BMI), smoking and cardiovascular risk index (based on BP levels, blood serum cholesterol levels and drinking habits), other variables, such as frequency of exercise practice, eating habits, and daily levels of stress, have an effect in cardiovascular health and endothelial function and that were not measured or controlled for in this study (Low et al. 2009; Myers 2003; Pascual-Teresa et al. 2010; Toda and Nakanishi-Toda 2011).

The second study found no evidence to support a relation between frequency of laughter at baseline and BP levels but found that infrequent laughter (in comparison to frequent laughter) was associated with increased BP in men who reported drinking at the beginning of the study, over a 4-year period. The changes in BP observed for this group of participants, although significant, was rather small, corresponding to a total decrease of 3.35% in SBP (Pre: $M = 129.8$, Post: $M = 134.3$) and of 4.07% in DBP (Pre: $M = 75.4$, Post: $M = 78.6$; Ikeda et al. 2020). These values are close to the net changes in SBP and DBP reported in our review for pre–post comparisons.

The two other longitudinal studies focused more specifically in cardiovascular health and both found that frequent laughter seems to be associated with improved health and lowered mortality (Hayashi et al. 2016; Sakurada et al. 2019).

Overall, it appears that the effect of LII is not universal, being dependent both on the characteristics of the interventions and those of the participants. In particular, interventions involving simulated laughter (e.g., laughter therapy, laughter yoga) seem to be associated with a larger decrease in BP. However, although providing a satisfactory indicator of the effects of laughter in BP regulation, these interventions do not allow a definitive indicator given that they usually involve other breathing and relaxation exercises.

In addition, we also hypothesize that this difference might be partially due to the amount of laughter produced in each type of intervention. One study directly comparing the effects of simulated versus spontaneous laughter found that participants in the simulated laughter condition produced significantly more laughter than participants in the genuine laughter condition, although this factor alone did not explain all differences in terms of the participant's cardiovascular responses to humor (Law et al. 2018). However, further studies are needed to investigate this hypothesis as most of the studies included in this review did not control or report the amount of laughter produced by participants.

Another factor that might have influenced participants' cardiovascular responses is their level of amusement by the activities included in the LII in which they participated. Specifically, although we observed greater effects in BP for participants who engaged in LII which involved simulated laughter, at least one study involving HRV seems to indicate that participants' amusement with the comedic material has a positive effect in mediating the effects of laughter on cardiovascular responses (Lackner et al. 2014). This finding might suggest that LII and humor might influence different aspects of cardiovascular activity differently and warrants further research.

Other individual factors, such as personality and sense of humor have also been found to influence the effectiveness of humor-based interventions, both in the short and long-term (Wellezohn et al. 2018); however, most of the studies included in this review did not account for these factors. As such, it remains

unclear whether they might also modulate or influence the physiological responses associated with LII.

For HRV, the studies also present inconsistent results. The most consistent finding appears to be that exposure to LII seems to be associated with increased SDNN. The SDNN is the “gold standard” for categorization of cardiovascular risk (when measured for a period of at least 24 h) and is an important predictor of morbidity and mortality (Schaffer and Ginsberg 2017). It is subject to the influence of both the sympathetic and parasympathetic nervous systems, and is usually highly correlated with VLF, LF and total power, although this relationship highly depends on the conditions in which the measurements are conducted (Schaffer and Ginsberg 2017).

In the studies included in our review exploring HRV, the data collection period was brief (all under 1 h to the best of our knowledge). In these cases, it seems that the primary source of variation is the parasympathetic nervous system. However, previous studies have argued that SDNN is more accurate when calculated over longer periods of time (at least 24 h), providing more precise information about cardiorespiratory regulations and central nervous system activity, among others (for a full review, see Shaffer and Ginsberg 2017).

The results observed for HRV seem to be in line with those reported by Kreibig (2010) regarding the increased SDNN. For BP, our results suggest some fluctuations associated with participation in LIIs, while in the review conducted by Kreibig (2010), BP is reported to remain unchanged. This difference might be explained by the fact that our review included more articles involving the effects of LIIs in BP, and by the fact that Kreibig’s review focused more broadly on amusement (as opposed to laughter).

Situating laughter in the context of its associated emotional response (i.e., mirth), our findings also seem to be congruent with past research that suggests a positive association between positive emotions and HRV (in particular, cheerfulness and calmness; Geisler et al. 2010), although these effects of positive emotions seem to be less durable than those caused by negative emotions (Broschot and Thayer 2003). This lack of durability might hinder experimental efforts to document the benefits of positive states (in this case, laughter) and also warrants further research to better comprehend the chronology of the physiological correlates of laughter.

Regarding the effects of laughter frequency in overall cardiovascular health, the studies included seem to support the hypothesis that there is a positive relation between these two variables. Whether this difference is due to the cumulative effects of laughter or due to other variables is still inconclusive; although this effect it is likely a combination of both.

For instance, other variables that might be positively correlated with laughter frequency such as positive psychological well-being, are also correlated to improved cardiovascular health, independently of traditional risk factors (Boehm and Kubzansky 2012). This effect appears to be due to the fact that positive psychological well-being seems to be associated with a higher number of health restorative behaviors (e.g., meditation) and with a lower number of harmful behaviors that might impact cardiovascular health.

Taken together, the difficulty in finding consistent physiological patterns in terms of the cardiovascular system stemming from the application of LII can also be explained by the existence of large intra and interindividual variability in responses. This reasoning is congruent with a more constructivist approach to emotions and their physiological correlate, which posits that physiological responses associated with specific emotional states are often “...*neither consistent nor specific*...” (Hoemann et al. 2020).

11 Limitations and future work

The quality of any systematic or meta-analytical review is largely determined by the quality of the primary sources included. Most of the evidence included in this review was evaluated as being weak or moderate and with some risk of bias, mostly due to the prevalence of small sample sizes, selection bias, and intervention integrity. Although the studies analyzed a wide range of interventions, lasting for variable amounts of time, the lack of consistency between a sufficiently large subset of studies complicates the task of withdrawing definite conclusions about important aspects, such as the adequate dosage, content, and effectiveness of LII. This was especially true for studies involving measures of HRV, which due to its smaller number, implicate a much higher level of uncertainty when attempting to extract overall conclusions. This poor quality, however, does not seem to be unique to the studies we included in our review, as it has been noted in other reviews focusing on the effects of humor and laughter on other variables (see for example, van der Wal and Kok 2019).

Similarly, we found that many of the studies lacked the reporting of important experimental and study-related information, such as the blinding of participants and researchers to treatment allocation and important confounding variables. Notably, in most studies, we found a lack of information about individual factors that can influence cardiovascular activity, such as health habits and characteristics (e.g., smoking, BMI) and medication or drug usage.

Furthermore, the small number of studies found to be congruent with our selection criteria did not allow us to explore other potentially relevant factors that might have influenced the indirect effects of laughter on the cardiovascular system (Hoemann et al. 2020). These variables include, for example, the valence of the comedic material employed (as well as its comparison with neutral LII, such as those employing simulated laughter) and the intensity or duration of the laughter episode.

In addition, in terms of evaluating the effectiveness of LII in decreasing BP and, to the best of our knowledge, there is still a significant lack of comparative approaches that attempt to situate the effect of these interventions when compared to other non-pharmacological interventions aimed at improving cardiovascular function. Future studies should thus expand the literature by considering the relative efficiency of this type of intervention by comparing it to other methods for improving cardiovascular health.

12 Main contributions

Humor and laughter have been linked to improved health both by the lay public and by researchers alike. Some researchers have argued that LIIs and humor-based interventions can function as an adjunctive therapy to improve conditions like depression and anxiety (Dogan 2020; van der Wal and Kok 2019). In this context, these interventions offer low-risk, cheap and scalable options to deliver those benefits. However, it is important to fully understand the physical health effects of LIIs before implementing them. To the best of our knowledge, this is the first systematic review specifically aimed at analyzing the impact of LII on cardiovascular health (namely, BP and HRV).

In this context, we analyzed the results of studies involving LII published until 2020, involving more than 20,000 participants from different geographical backgrounds and with different socio-demographic characteristics. In addition, we sought to add value by analyzing and comparing results obtained from studies employing different study designs, so we could offer a more comprehensive view of the effects of LII in different groups of people.

The results of this review offer a first systematic glance at the effects of LII on the cardiovascular system. Although definitive conclusions cannot yet be drawn, we expect that this review stimulates further research and offers new insights and avenues of development for the creation, evaluation and implementation of LII.

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