The constraint-led approach to enhancing team synergies in sport - What do we currently know and how can we move forward? A systematic review and meta-analyses

RAMOS, A., COUTINHO, P., LEITÃO, J.C., CORTINHAS, A., DAVIDS, Keith <http://orcid.org/0000-0003-1398-6123> and MESQUITA, I.

The Constraint-led approach to enhancing team synergies in sport - What do we know so far and how can we move forward? A systematic review with meta-analysis

Ana Ramos[1], Patrícia Coutinho[1], José Carlos Leitão[2,3], António Cortinhas[3], Keith Davids[4], & Isabel Mesquita[1]

[1] CIFI2D, Faculty of Sport, University of Porto, Porto, Portugal

[2] CIDESD e Research Center in Sports, Health Sciences and Human Development, Portugal

[3] Department of Sport Sciences Exercise and Health, University of Trás-os-Montes e Alto Douro, 5001-081 Vila Real, Portugal

[4] Centre for Sport Engineering Research, Sheffield Hallam University, Sheffield, UK

Abstract

During the past decades, Constraint-led approach (CLA) has been become increasingly popular as a methodology in sports sciences to support athlete development and preparation for performance. More recently, there has been increasing interest in how athletes' attunement to shared affordances guides the emergence of synergetic behaviours in sports teams. Given the growing amount of research information emerging, this study aimed to quantify and compare findings related to two key measures of synergy formation in sports teams, identified in contemporary research: dimensional compression and reciprocal compensation. A literature search was conducted for articles published until December 2018, on electronic databases PubMed, Scopus, EBSCO, SPORTDiscus, Web of Science, and Google Scholar. Inclusion criteria were defined before the selection process. From the selected articles we extracted information on: authors, year of publication, study design, study context, sample, sport, variables assessed, type of constraints manipulated, statistical methods, and main findings. The methodological quality of manuscripts was assessed using the Downs and Black checklist. A meta-analysis was performed using a random-effects model and subgroup analyses were conducted for the two potential moderators of dimensional compression and reciprocal compensation. A total of 47 and 24 studies met the inclusion criteria for systematic and meta-analysis, respectively. Results revealed that investigations tended to predominantly focus on evaluation of how manipulation of task constraints shape competitive behaviours of predominantly male football players during training. There was a higher level of heterogeneity across studies, possibly justified by diversity of metrics applied to assess players' performance behaviours. Additionally, the level of research heterogeneity observed also supports the assumption that variable behaviours enhance the capacity of sports teams for adaptation. Publication

and inflation biases were observed in the literature, highlighting the need to adopt methods to avoid these systematic flaws in future investigations to prevent biased assumptions from existing evidence.

Keywords: constraints-led approach, team synergies, quantitative review, team sports performance, practice learning designs, research methods

Introduction

Grounded on concepts of dynamical systems theory and ecological psychology, integrated in an ecological dynamics rationale (e.g., Chow, Davids, Button, Shuttleworth, & Araújo, 2007), the CLA seeks to understand how athletes and teams coordinate and adapt their behaviours under interacting task, individual, and environmental constraints (Davids & Araújo, 2005; Renshaw, Chow, Davids, & Hammond, 2010). Constraints are conceptualised as boundaries that shape the emergence of behaviour (Newell, 1986), facilitating opportunities for individuals to interact with the environment (i.e., affordances) (Gibson, 1979). Due to its ecological scale of analysis, the CLA is viewed as an *athlete-environment centred* approach (Renshaw et al., 2016). Generally, most studies using a CLA have focused on how manipulating different task constraints shapes athletes': (i) goal-oriented behaviours, (ii) decision-making, or (iii), collective behaviours in teams.

Given the amount of information continuously emerging from studies of team sports performance adopting a CLA methodology, summaries of the main research findings are constantly needed to update our understanding. Thus, systematic reviews and/or meta-analysis are needed to provide an opportunity to estimate the magnitude of statistical differences reported across emerging studies.

To exemplify, in a study of practice learning designs in team sports, Ometto et al. (2018) published a systematic review to investigate which task constraints have been most frequently manipulated when using small sided and conditioned games (SSCGs) during practice. Their review also reported the impact of such manipulations on emerging tactical behaviours, technical actions, and co-positioning between participants. They found that studies tended to manipulate only one or two constraints during training, most frequently involving changes in numerical relations between

players (overloading and underloading) and playing area dimension values. Although an important contribution, the study by Ometto et al. (2018) only included investigations of SSCG designs in training sessions and their participants were only footballers. In assessing decision-making, their analysis of experimental protocols implemented in past research revealed a repeated failure of practice designs to reproduce representative performance conditions. This issue was also highlighted by Travassos et al. (2013) in another meta-analysis examining effects of responses and methods of stimulus presentation when assessing decision-making expertise in sport. They concluded that representative task constraints seemed to be the most functional empirical protocols to enhance validity of data in research investigations. Despite the relevance of these studies, currently some pertinent questions remain unanswered concerning how the CLA has been applied in research on team sports. For instance, what types of samples have been largely examined? What study designs have been mainly utilised? Which study contexts (i.e., training or competitive performance environments) have been preferred? Which collective behaviours have been most frequently analysed?

Within sports practice designs, collective behaviours in sports teams (i.e., team tactical behaviours) have been defined as *synergetic behaviours* (behaviours of the team or sub-groups in a team acting synergistically) (Araújo & Davids, 2016). These collective system behaviours emerge as a consequence of athletes' perceptual attunement to shared affordances (individuals learning to pick up and use opportunities for action in the environments) (Silva, et al. 2013). According to Araújo and Davids (2016) team synergetic behaviours comprise four properties: (i) dimensional compression, (ii) reciprocal compensation, (iii) interpersonal linkage, and (iv), system degeneracy. Previous analyses of team synergetic behaviours have highlighted the significance ofdimensional compression (i.e., a process of decreasing dimensionality

which emerges through the increased coupling of hitherto independent degrees of freedom) and reciprocal compensation (i.e., adaptative behaviours of other athletes, when a teammate does not fulfil a function, in order to achieve a task goal) (Araújo & Davids, 2016; Beek & Daffertshofer, 2014; Latash, 2008). Many studies have investigated how constraints manipulation in learning design may affect player and/or team synergetic behaviours (e.g., Olthof, Frencken, & Lemmink, 2017; Silva et al., 2016a; Travassos, Coutinho, Gonçalves, Pedroso, & Sampaio, 2018). However, to date, no systematic reviews with meta-analyses have emerged in the literature, considering how CLA concepts have been applied to the analysis of synergetic behaviours in sports teams.

Thus, through a systematic review and meta-analysis process the purpose of the present study was to quantify and compare findings related to key properties of dimensional compression and reciprocal compensation in team sports, shaped by player, task, and environment constraints manipulations. We expected to draw evidence-based conclusions that may guide future academic investigations and coaching practice.

Methods

Data sources and search strategy

A systematic review and meta-analysis were conducted in accordance with the recommendations outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Moher et al., 2015). An electronic literature search was undertaken for articles published up to, and including, December 2018, on the online databases PubMed, Scopus, EBSCO, SPORTDiscus, Web of Science, and Google Scholar. The search terms, the search strategy and the respective results by

database are presented in Table 1. The reference lists of the selected articles were also screened for potentially suitable articles to include in the review.

Then, titles and abstracts of retrieved articles were individually evaluated by a research team to assess their eligibility for review and meta-analysis. The reviewers were not blinded to the list of authors, the institutions or the journals of publication in the selected studies. Any disagreements on study selection were resolved consensually. The study abstracts that did not provide enough information according to the eligibility criteria stabilised were retrieved for full-text evaluation.

This study was approved by the local Institutional Research Ethics Committee (CEFADE 26.2018) and followed the recommendations of the Declaration of Helsinki (1964).

** please insert table 1 around here**

Eligibility criteria

After recommendations of Simmons, Nelson, and Simonsohn (2011), eligibility criteria and the type of variables under analysis were defined prior to the electronic search. In order to maintain quality assurance, and due to the possibility that reported data had not been put through an independent, expert peer-review process, conference abstracts, chapters, dissertations, and theses, were excluded from analyses. For the same reason, articles published in non-peer-reviewed journals and/or those without an indexed impact factor were also left out. Peer-reviewed studies were included taking into account the following criteria: (i) the article had to focus on theoretical concepts from a constraint-led approach (see Table 1) applied to the analysis of dimensional compression and/or reciprocal compensation properties, within a training or competitive performance context; (ii) the articles had to be empirical and use quantitative research

methods; and (iii), the article had to be written in English language with full-text available, and published in a journal with an indexed impact factor. In addition, no restrictions were placed on participants' age, skill or gender. Finally, articles on both individual and team sports were included in the systematic review. However, due to unsuitable data formats, the meta-analysis only encompassed studies focused on team sports.

Data extraction

The systematic search yielded 47 studies and the following information from these was recorded: Authors' names, year of publication, study design (i.e., cross-sectional or longitudinal), study context (i.e., training or competitive performance environments), sample characteristics, the specific sport context, variables assessed, type of constraints manipulated (i.e., task, athlete, and environment), statistical methods, and main findings.

Specifically, we considered age and expertise level as athlete (organismic) constraints. Key moments of performance, the competitive performance environment per se, and match status were considered as environmental constraints. Finally, task constraints included team tactical variables, such as: number of targets used in training practices, numerical relations between players in SSCGs, small sided games formats, rules, field dimensions, and relative co-positioning among players. All data were tabulated in an Excel spreadsheet (Microsoft Corporation, Redmond, WA, USA) predesigned for this review. Studies which did not afford enough or appropriate information to conduct a meta-analysis were still assessed for methodological quality and reported in review summary table (see Appendix 1).

Study quality assessment

The assessment of methodological quality of the studies included was completed through the validated Downs and Black checklist (Downs & Black, 1998). This scale offered us the possibility to emphasize the strongest and weakness points of each study under assessment, as well as to evaluate studies that did not report randomized control trials (Bento, 2014). The checklist encompasses 27 items that are intended to evaluate the reporting, validity, and statistical power of the published reports. Specifically, items 1-10 refer to reporting, items 1-13 related to external validity, items 14-26 refer to internal validity, and item 27 regards to the statistical power. Study quality was classified as in the study of Grgic et al. (2018): categorised as 'good quality' if they scored 20-29 points, 'moderate quality' if they scored 11-20 points, and 'poor quality' if they scored < 11 points.

Data Analysis

The effect size measures for each variable identified were standardized through measures of mean and standard deviations, correlations coefficients, Cohen's d values, and T-test values. Considering the methodological differences across studies (i.e., sample, statistical procedures) a random effect model was used as recommended by Field and Gillett (2010). The values of effect size were interpreted as >0.2 (small), >0.5 (moderate), and >1.2 (large) (Cohen, 1988).

The heterogeneity across the studies was assessed using Q-test and quantified through I^2 statistics. The I^2 is a quantitative measure of inconsistency across studies, which could be quantified as: homogenous (<25%), low (25%-50%), moderate (50%-75%), and high (>75%) (Higgins, Thompson, Deeks, & Altman, 2003). Further, the estimation of publication bias was assessed through a rank correlation test (Begg &

Mazumdar, 1994), and Egger's test (Egger, Smith, Schneider, & Minder, 1997). All the tests were set with a significance level of $\alpha < 0.05$, and were 2 tailed, except for the bias-related tests, which were 1 tailed. The entire data set was transformed and computed in the Comprehensive Meta-Analysis software package, 2008 (BioStat, Englewood, New Jersey).

Moderator variables

Among the four synergetic properties discussed in the study by Araújo and Davids (2016), the properties of dimensional compression and reciprocal compensation have received the most investigative analysis in contemporary research. For that reason, we selected them as potential moderator variables during the subgroup analysis. In line with the recommendations of Araújo and Davids (2016), measures of geometric centre (or centroid, or weight centroid), stretch index (or relative stretch index), effective playing space (or surface area, or convex hull), team spread, team width, team length, and team length per width ratio were codified as dimensional compression properties (i.e., first moderator). The reciprocal compensation properties (i.e., second moderator) included measures of relative phase, cluster phase, and running correlations.

Results

Studies selection

The search strategy described above yielded 769 articles through databases or other sources. Scanning the reference lists did not result in the inclusion of any additional studies. After duplicates were removed, 550 studies were excluded based on title or abstract. Full-text of the 192 remaining articles was assessed for eligibility, of which 47 were included in a qualitative review. Concerning the quantitative analysis,

only 24 studies met the inclusion criteria. The stages of the search and study selection process are presented in Figure 1.

please, insert figure 1 around here

Studies Characteristic

The general characteristics of studies included in qualitative and quantitative analyses are summarised in Table 2. In the sample of manuscripts selected involving both types of analyses, it can be observed that the studies selected mainly implemented a cross-sectional design where commonly experimental protocols were applied within training environments. A prevalence for analysis of performance in samples of male participants was also observed and studies mainly focused on team sports of Football and Futsal, as well as Rugby Union, Basketball, and Tennis. Constraints related to practice task design were most frequently manipulated, followed by those in the environment and individual (organismic) categories.

please insert table 2 around here

Methodological Quality

Both the systematic review and meta-analysis followed the same methodological quality trends. Thus, the average score on the Downs and Black checklist was 13 (range 10-16). One study was assessed as methodologically poor, while the remaining investigations were evaluated as having moderate methodological quality. None of the studies included were classified as being of good methodological quality. Regarding the studies included in the meta-analysis, the average score was 13 (range 10-16). The general quality assessment scores of studies are presented in Figure 2.

Further analyses revealed the presence of publication bias, assessed by Begg's (p=0.006) and Egger's (p=0.03) tests.

please insert figure 2 around here

Meta-analysis of outcome measures

The meta-analysis results regarding assessment of team synergetic properties are presented in Table 4. The I^2=99.743% (p=0.000) measure indicates the presence of significative and higher levels of heterogeneity between studies, which was confirmed by analysis of the forest plot (see Figure 3).

please insert table 4 and figure 3 around here

Meta-analysis of subgroup analysis

Table 5 shows that moderator variables selected are significant (p=0.03), indicating that these were suitably selected. However, the heterogeneity values remained significantly higher (I^2=99.753%), meaning that the differences *across* studies (i.e., differences in analyses of teams' synergetic behaviours) are not fully explained by each these two synergetic properties (dimensional compression and reciprocal compensation). Following the recommendations of Field and Gillett (2010), an additional exploratory analysis of heterogeneity was performed with the purpose of finding other moderators variables which could possibly explain the higher heterogeneity values. Accordingly, the geometric centre values in teams studied in the sport of Football were analysed due their frequency of analysis in the sample. However, we did not observe decreases in heterogeneity values.

please insert Table 5 around here

Discussion

The present study aimed to quantify and compare research findings related to dimensional compression and reciprocal compensation synergetic properties in team sports, considering player, task, and environment constraints. Overall, typically cross-sectional design studies were used in the literature to explore how the manipulation of different task constraints may affect the tactical behaviours of male players' and/or teams within training sessions. A higher level of heterogeneity (i.e., higher variability) across studies selected for meta-analysis was observed, mainly due to the diversity of methodological and statistical procedures used. Given the huge amount of information collected, our discussion of main findings was structured to selectively consider several key issues.

(i) Issues about study designs and contexts

Results indicated that cross-sectional designs (n=45) were the most frequently used. Corroborating the results reported by Ometto et al. (2018), few longitudinal studies (n=2) were found, possibly due to the difficulties in collecting data across several occasions in team training schedules (Caruana, Roman, Hernández-Sánchez, & Solli, 2015). In general, longitudinal studies where collective behaviours were explored focused their analyses on team coordination movements, showing that: (i) team movements are grounded on the formation of synergies between players (Silva et al., 2016a), and (ii), as the variability of contextual performance situations increased, speed

of team coordination decreased (Gonçalves et al., 2018a). However, as suggested by Silva et al. (2016a), to develop understanding of team collective behaviours, future research also requires an analysis of team asymmetric movements, since they may represent a specific team strategy.

Concerning study contexts, when compared to those undertaken in the competitive performance environment (n=12), almost three times the number of studies were conducted within training contexts (n=35). In fact, as argued by Carling, Reilly, and Williams (2009), information obtained from observation of performance in the competitive performance environment, forms one of fundamental bases for designing weekly training programs. Particularly the evidence from previous competitive matches, could be extremely useful to build specific, representative learning scenarios in training, resulting in different constraints manipulation, according to the needs of individual players or sub-groups in the team. Furthermore, most investigations of team performance in training sessions have failed in explain: (i) why different constraints manipulations were integrated and implemented in practice, and (ii), what individual or collective problems (i.e., technical, tactical, etc.) were targeted (Correia et al., 2012; Gonçalves et al., 2017b). Usually such protocols are implemented during a small part of the training session, without the provision of information about occurrences in the other parts of training sessions (Esteves et al., 2012; Silva et al., 2014a).

(ii) Issues about sample and sport

Typically, samples of male team games players (n=39) were investigated, with only one study integrating females and males within the same sample. This seems to represent a gender bias that is intrinsic in sport science research on team games performance at the moment, which needs to be corrected by an increase in investigations of effects of constraints manipulations on female team games players.

This is especially important given the continuing rise in popularity of women's competitions in many team games like Association Football (soccer) and Rugby Union.

In addition, physical and maturational differences between girls and boys of different age groups in samples (Cumming, Standage, Gillison, & Malina, 2008; Ramos et al., 2018) could lead to variations in responses to constraints manipulations during practice. This effect should be taken into consideration by practitioners in the design of learning tasks. Children should not be treated as 'mini-adults' in preparation for sport performance.

(iii) Issues about type of constraints manipulated

In agreement with the outcomes of studies by Aguiar, Botelho, Lago, Maças, and Sampaio (2012) and Ometto et al. (2018), our results depicted that the most typically manipulated constraints were related to the specific task undertaken (n=33), followed by environmental (n=12) and organismic (athlete) (n=12) constraints. Specifically, the most frequently manipulated task constraints were related to playing area dimensions (i.e., pitch size and practice spaces), numerical relations between players in different teams (i.e., using equal and unequal numbers of players in competing teams), and the imposed rules of practice matches. The studies where playing dimension and space were manipulated revealed that larger playing areas promoted: (i) higher variability in player movements (Silva et al., 2014c), (ii) more opportunities for creating overloads (gaining numerical advantage) (Silva et al., 2015), (iii) higher levels of physical performance (Olthof et al., 2017), as well as (iv), an elongated team playing shape (Silva et al., 2014a). Moreover, studies focusing on the role of manipulating player numbers involved in SSCGs suggested that numerical relations between teams clearly constrained intra-team coordination, mainly in situations of numerical disadvantages between competing teams (Silva et al., 2014b; Travassos, Vilar, Araújo, & McGarry,

2014b). Finally, Silva et al. (2014a) found that players and teams self-organized according to the specific game rules applied during SSCGs.

There are two reasons behind the significant research interest in manipulating task constraints. First, there is a consensual idea that breaking the full game into smaller phases or tasks (for instance, practising technical or tactical tasks within a specific game sub-phase) guides learners' attentional focus to enhance their understanding and performance(Ford, Yates, & Williams, 2010; Travassos, Duarte, Vilar, Davids, & Araújo, 2012d). Second, interpretations of Newell's constraints model (Newell, 1986) with reference to team sports performance (e.g., Handford et al., 1997), have suggested that organismic constraints (of players) concern physical characteristics of each player (e.g., morphological characteristics), while environmental constraints encompass how physical and social conditions influence performance (e.g., weather and crowd size). In this sense, task constraints have been considered the easiest available to be manipulated by sport practitioners, as revealed in past research analyses.

(iv) Issues about team synergetic behaviours

Analysis of studies selected indicated that the property of dimensional compression (n=16) has been highlighted in the literature more frequently than reciprocal compensation (n=8). The latter has received less attention in the literature, corroborating the arguments of Araújo and Davids (2016). Globally, studies focused on dimensional compression have suggested that players are able to co-adapt (i.e.., self-organize) their behaviours in response to manipulation of several task constraints (e.g., Fitzpatrick, Davids, & Stone, 2016; Oppici, Panchuk, Serpiello, & Farrow, 2018; Tan, Chow, Duarte, & Davids, 2017). Additionally, studies of reciprocal compensation has revealed that: (i) there is a mutual influence on the synchronization process between teams, (ii) intra-team coordination decreases in situations when teams are losing, (iii) defensive

lines are better coordinated than offensive lines, (iv) players are commonly coordinated with ball displacement, and (v), players synchronize their moves according to their most immediate opponent (Duarte, Araújo, et al., 2013; Folgado, Gonçalves, & Sampaio, 2018; Luís Vilar et al., 2014b).

There is a need to evaluate these properties during official competitive performance and according to the specificities of different team sports. There remains, also, scarce research identifying reliable predictors of team synergetic behaviours (e.g., maintaining or winning possession of the ball, current match status)

(v) Issues statistical methods

Throughout the analysis of the studies selected for systematic review, we identified a vast and distinct number of metrics applied, suggesting that there is a methodological adjustment according to the sport and the synergetic property under analysis.

As identified by Araújo, Silva, and Ramos (2014), our analysis showed that the property of dimensional compression has been captured through analysis of the variable 'team centre' (e.g., weight centroids) and team dispersion metrics (e.g., stretch index, effective playing space, team spread, among others). Concerning the analysis of reciprocal compensation, initially studies focused on the analysis of dyads (1v1s), through using the relative phase method (Duarte et al., 2010). However, the need to explain how actions of different players become synchronized within the collective behaviours of a team have led to favouring of a distinct metric – the cluster phase method, based on the Kuramoto order parameter (Duarte, Araújo, et al., 2013). Nowadays, the exploration of hypernetworks seeks to simultaneously observe the cooperative and competitive interactions between teammates and opponents across the space-time scale during a competitive match (e.g., Ramos, Lopes, Marques, & Araújo, 2017; Ribeiro et al., in press).

Indeed, a deep analysis of complex system behaviours cannot be assessed through using simple linear measures, and for that reason the use of several sophisticated non-linear measures has been applied in the sport sciences (Silva, Duarte, Esteves, Travassos, & Vilar, 2016). Despite their undeniable contribution, such methodological diversity has made it challenging to identify patterns of behaviour and interpret the main findings across studies.

(vi) Issues about meta-analysis

The meta-analysis results of our study portrayed a higher level of heterogeneity across studies. As expressed by systematic analysis results discussed above, the assessment of several sports, distinct populations, the diversity of variables under analysis, the use of a wide range of different metrics in statistical procedures, and the manipulation of different constraints, could possibly have contributed to this outcome.

In addition, the subgroup analysis did not reveal differences in heterogeneity levels, possibly because several metrics could be used to assess each synergetic property, in agreement with the reasons mentioned above. Notwithstanding, it is worth noting that the quantitative analysis performed evaluated the players' behaviours. Indeed, it is not expected that a behaviour would remain constant under different practice scenarios (i.e., constraints manipulation). Indeed, the literature on a CLA has suggested that a greater variability of players' tactical behaviours provides them with capacities to self-organize, and consequently, co-adapt to any context with the purpose of satisfying the performance or task demands (Passos et al., 2009; Paulo, Davids, & Araújo, 2017; Travassos et al., 2016). Following this rationale, the heterogeneity found between studies selected supports this thesis: that variable scenarios promote flexible behaviours which, in turn, afford adaptable actions. Accordingly, the heterogeneity

found in our analysis, besides being unexpected, seems to be positive, desirable, and functional. However, with the aim of confirming this hypothesis, we strongly encourage the replication of some experimental protocols in future investigations.

Finally, the presence of bias could possibly reflect both publication and inflation bias within this research field. The publication bias consists of considering only studies that provide statistically significant results (i.e., $p<0.05$) (Simonsohn, Nelson, & Simmons, 2014). This decision may have removed from the literature base studies where results may have not confirmed hypotheses or were considered negative, including false negatives. Inflation bias concerns the exhaustive exploration of data using different statistical approaches, which introduces in the literature true or false positives (Head, Holman, Lanfear, Kahn, & Jennions, 2015). This finding highlights the need to take some methodological care in future academic studies in order to reverse this trend, otherwise this may lead us systematically towards overoptimistic (and false) conclusions.

(vii) Limitations

Several limitations may be acknowledged in the present investigation. First, it is plausible that some published literature may not have been identified, even following all the comprehensive searches of databases and systematic steps reported. Second, several studies did not report suitable measures (degrees) to perform a meta-analysis. For instance, commonly studies where relative phase methods were used refers to in-phase states where the relative phase is near zero degrees and anti-phase states where the relative phase is near 180º. Also, several studies used Analysis of Variance (ANOVA) and Multivariate Analysis of Variance (MANOVA) without reporting the eta-square measure or descriptive measures avoiding effect size calculations. Third, when the designs across studies included in meta-analyses were heterogeneous, we tried to

counter this issue by employing a random-effects model (Higgins, 2008) and performing different explorative sub-group analyses. For this reason, the results should still be interpreted with caution.

(viii) Future Research

As our results highlighted, there is a lack of investigations of female players' behaviours during competitive performance. In addition, there is also a dearth of studies that have compared evaluations of the players' behaviours during competitive performance with those observed in specific and representative learning designs during training sessions (i.e., action fidelity analysis, see Travassos et al. (2012d)). Therefore, we recommend this type of analysis in future research. Indeed, this type of investigation will offer the opportunity to evaluate the quality of practice designs. Here, an action-research design could fit well with this purpose. Furthermore, future studies could present an appropriate contextualization of constraints manipulation inside the whole training process (i.e., Why and how specific constraints are manipulated? What technical/tactical problem does the manipulation seek to resolve?). This approach will clearly inform, both academics and coaches, about how to use several pedagogical strategies in order to optimize the holistic development of players and teams.

(ix) Practical Implications for coaches

The take home message for coaches encourages them to keep integrating constraints manipulation in their learning designs (e.g. field dimension, player numbers, rules, time of execution, time of visualization, amongst others). However, it is important to note that the manipulation of constraints should consider: (i) the specificities of each sport, the tactical and technical problems that need to be resolved, the players' level of experience and performance. Also, the addition of constraints must be, as much as

possible, congruent with the specific competitive demands of each sport. In other words, coaches should focus on building representative (i.e., training stimulus in accordance with competitive stimulus) learning environments.

Conclusions

Overall, the systematic review analysis suggested that cross-sectional investigations have been focused on evaluating how the manipulation of task constraints may affect male football players and teams during training sessions. In addition, the analysis of team synergetic properties has been undertaken through vast and distinct metrics, with dimensional compression analysis receiving more attention in the literature. The diversity of statistical procedures applied possibly explains the heterogeneity observed in the studies selected for meta-analysis. This observation supports the assumption that variable behaviour, as a response to the manipulation of different constraints, offers opportunities for adaptability in the tactical behaviours of team players. Therefore, such heterogeneity may be functional and desirable. Finally, we conclude there is a presence of publication and inflation bias within this research field, which highlighted the need for researchers to take more methodological care in future investigations.

Funding

This work was supported by the Foundation for Science and Technology (FCT, Portugal) through the SFRH/BD/126387/2016 grant awarded to the first author.

References

Aguiar, M., Botelho, G., Lago, C., Maças, V., & Sampaio, J. (2012). A Review on the Effects of Soccer Small-Sided Games. *Journal of Human Kinetics, 33*(1), 103-113. doi:10.2478/v10078-012-0049-x

Araújo, D., & Davids, K. (2016). Team Synergies in Sport: Theory and Measures. *Frontiers in Psychology, 7*(1149).

Araújo, D., Silva, P., & Davids, K. (2015). Capturing group tactical behaviours in expert teams players. In J. Baker & D. Farrow (Eds.), *Routledge Handbook of Sport Expertise* (pp. 209-220). New York, NY: Routledge.

Araújo, D., Silva, P., & Ramos, J. P. (2014). Affordance-based decisions guides team synergies during match performance. *Research in Physical Education, Sport and Health, 3*(1), 19-27.

Beek, P., & Daffertshofer, A. (2014). Dynamical systems. In R. Eklund & G. Tenenbaum (Eds.), *Encyclopedia of Sport and Exercise Psychology* (Vol. 4, pp. 224-229). Thousand Oaks, CA: SAGE Publications).

Begg, C. B., & Mazumdar, M. (1994). Operating Characteristics of a Rank Correlation Test for Publication Bias. Biometrics. *Biometrics*, 1088-1101.

Bento, T. (2014). Guidelines for planning, conducting, reporting and evaluating Systematic Reviews in Sport and Health. *Motricidade, 10*(2), 107-123.

Carling, C., Reilly, T., & Williams, A. (2009). *Performance assessment for field sports* (1st ed.). London: Routledge.

Caruana, E. J., Roman, M., Hernández-Sánchez, J., & Solli, P. (2015). Longitudinal studies. *Journal of Thoracic Disease, 7*(11), 537-540.

Chow, J. Y., Davids, K., Button, C., Shuttleworth, R., & Araújo, D. (2007). The Role of Nonlinear Pedagogy in Physical Education. *Educational Research, 7*(3), 251-278.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (L. E. Associates. Ed.). Hillsdale.

Correia, V., Araújo, D., Duarte, R., Travassos, B., Passos, P., & Davids, K. (2012). Changes in practice task constraints shape decision-making behaviours of team games players. *Journal of Science and Medicine in Sport, 15*, 224-249.

Cumming, S. P., Standage, M., Gillison, F., & Malina, R. M. (2008). Sex Differences in Exercise Behavior During Adolescence: Is Biological Maturation a Confounding Factor? *Journal of Adolescent Health Care, 42*, 480-485. doi:10.1016/j.jadohealth.2007.10.005

Davids, K., & Araújo, D. (2005). The Constraints-led Approach in Sport Training. In D. Araújo (Ed.), *The context of decision. The Tactical Action in Sport.* (pp. 35-60). Lisbon: Visão e Contextos.

Downs, S., & Black, N. (1998). The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *Journal of Epidemiology and Community Health, 52*, 377-384.

Duarte, R., Araujo, D., Correia, V., Davids, K., Marques, P., & Richardson, M. J. (2013). Competing together: Assessing the dynamics of team-team and player-team synchrony in professional association football. *Human Movement Science, 32*(4), 555-566. doi:10.1016/j.humov.2013.01.011

Duarte, R., Araújo, D., Correia, V., Davids, K., Marques, P., & Richardson, M. J. (2013). Competing together: Assessing the dynamics of team–team and player–team synchrony in professional association football. *Human Movement Science, 32*, 555-566.

Duarte, R., Araújo, D., Gazimba, V., Fernandes, O., Folgado, H., Marmeleira, J., & Davids, K. (2010). The Ecological Dynamics of 1v1 Sub-Phases in Association Football. *The Open Sports Sciences Journal, 3*, 16-18.

Egger, M., Smith, G. D., Schneider, M., & Minder, C. (1997). Bias in meta-analysis detected by a simple, graphical test. *BMJ Clinical Research, 315*, 629-634.

Esteves, P., Araújo, D., Davids, K., Vilar, L., Travassos, B., & Esteves, C. (2012). Interpersonal dynamics and relative positioning to scoring target of performers in 1 vs. 1 sub-phases of team sports. *Journal of Sports Sciences, 30*(12), 1285-1293.

Field, A. P., & Gillett, R. (2010). How to do a meta-analysis. *British Journal of Mathematical and Statistical Psychology, 63*, 665-694.

Fitzpatrick, A., Davids, K., & Stone, J. A. (2016). Effects of Lawn Tennis Association mini tennis as task constraints on children's match-play characteristics. *Journal of Sports Sciences*, 1-8.

Folgado, H., Gonçalves, B., & Sampaio, J. (2018). Positional synchronization affects physical and physiological responses to preseason in professional football (soccer). *Research in Sports Medicine, 26*(1), 51-63. doi:10.1080/15438627.2017.1393754

Ford, P., Yates, I., & Williams, A. M. (2010). An analysis of practice activities and instructional behaviours used by youth soccer coaches during practice: exploring the link between science and application. *Journal of Sports Sciences, 28*(5), 483-495.

Gibson, J. J. (1979). *The Ecological Approach to Visual Perception*. Boston: Houghton Miffin.

Gonçalves, B., Coutinho, D., Travassos, B., Folgado, H., Caixinha, P., & Sampaio, J. (2018a). Speed synchronization, physical workload and match-to-match performance variation of elite football players. *PLoS ONE, 13*(7).

Gonçalves, B., esteves, P., Folgado, H., Ric, A., Torrents, C., & Sampaio, J. (2017b). Effects of Pitch Area-Restrictions on Tactical Behavior, Physical, and Physiological Performances in Soccer Large-Sided Games. *Journal of Strength and Conditioning Research, 31*(9), 2398-2408.

Grgic, J., Schoenfeld, B. J., Davies, T. B., Lazinica, B., Krieger, J. W., & Pedisic, Z. (2018). Effect of Resistance Training Frequency on Gains in Muscular Strength: A Systematic Review and Meta-Analysis. *Sports Medicine, 48*(5), 1207-1220.

Head, M. L., Holman, L., Lanfear, R., Kahn, A. T., & Jennions, M. D. (2015). The Extent and Consequences of P-Hacking in Science. *PLoS Biology, 13*(3), 1-15. doi:10.1371/journal.pbio.1002106

Higgins, J. (2008). "Commentary: Heterogeneity in meta-analysis should be expected and appropriately quantified." International Journal of Epidemiology **37**(5): 1158-1160.

Higgins, J., Thompson, S., Deeks, J., & Altman, D. (2003). Measuring inconsistency in meta-analyses. *BMJ (Clinical Research Ed.), 327*, 557-560.

Latash, L. (2008). *Synergy*. New York, NY: Oxford University Press.

Liu, H., Gómez, M.-A., Gonçalves, B., & Sampaio, J. (2016). Technical performance and match-to-match variation in elite football teams. *Journal of Sports Sciences, 34*(6), 509-518.

Machado, J. C., Alcântara, C., Palheta, C., Dos Santos, J. O. L., Barreira, D., & Scaglia, A. J. (2016). The influence of rules manipulation on offensive patterns during small-sided and conditioned games in football. *Motriz. Revista de Educacao Fisica, 22*(4), 290-298. doi:10.1590/S1980-6574201600040012

Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., . . . Stewart, L. A. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Syst Rev, 4*, 1. doi:10.1186/2046-4053-4-1

Newell, K. M. (1986). Motor development in children: Aspects of coordination and control. In M. G. W. H. T. A. Whiting (Ed.), *Constraints on the development of co-ordination* (pp. 341-360).

Olthof, S. B. H., Frencken, W. G. P., & Lemmink, K. A. P. M. (2017). Match-derived relative pitch area changes the physical and team tactical performance of elite soccer players in small-sided soccer games. *Journal of Sports Science*, 1-7. doi:10.1080/02640414.2017.1403412

Ometto, L., Vasconcelos, F., Cunha, F., Teoldo, I., Souza, C., Dutra, M., . . . Davids, K. (2018). How manipulating task constraints in small-sided and conditioned games shapes emergence of individual and collective tactical behaviours in football: A systematic review. *International Journal of Sports Science and Coaching, 0*(0), 1-15.

Oppici, L., Panchuk, D., Serpiello, F. R., & Farrow, D. (2018). The influence of a modified ball on transfer of passing skill in soccer. *Psychology of Sport and Exercise, 39*, 63-71. doi:10.1016/j.psychsport.2018.07.015

Ortega-Toro, E., García-Angulo, A., Giménez-Egido, J. M., García-Angulo, F. J., & Palao, J. (2018). Effect of modifications in rules in competition on participation of male youth goalkeepers in soccer. *International Journal of Sports Science and Coaching*. doi:10.1177/1747954118769423

Passos, P., Araújo, D., Davids, K., Gouveia, L., Serpa, S., Milho, J., & Fonseca, S. (2009). Interpersonal pattern dynamics and adaptive behavior in multiagent neurobiological systems: conceptual model and data. *Journal of Motor Behavior, 41*(5), 445-459.

Paulo, A., Davids, K., & Araújo, D. (2017). Co-adaptation of ball reception to the serve constrains outcomes in elite competitive volleyball. *International Journal of Sports Science & Coaching*. doi:10.1177/1747954117722727

Plaza, M., Boiché, J., Brunel, L., & Ruchaud, F. (2017). Sport = Male…But Not All Sports: Investigating the Gender Stereotypes of Sport Activities at the Explicit and Implicit Levels. *Sex Roles, 76*, 202-217.

Ramos, J., Lopes, R., Marques, P., & Araújo, D. (2017). Hypernetworks Reveal Compound Variables That Capture Cooperative and Competitive Interactions in a Soccer Match. *Frontiers in Psychology, 8*. doi:10.3389/fpsyg.2017.01379

Ramos, S., Volossovitch, A., Ferreira, A., Barrigas, C., Fragoso, I., & Massuça, L. (2018). Differences in maturity,morphological, and fitness attributes between the better- and lower-ranked male and female u-14 portuguese elite regional basketball teams. *Journal of Strength and Conditioning Research, 0*(0), 1-10.

Renshaw, I., Araújo, D., Button, C., Chow, J. Y., Davids, K., & Moy, B. (2016). Why the Constraints Led Approach is not Teaching Games for Understanding a clarification. *Physical Education and Sport Pedagogy, 21*(5), 459-480.

Renshaw, I., Chow, J. Y., Davids, K., & Hammond, J. (2010). A constraints-led perspective to understanding skill acquisition and game play: a basis for integration of motor learning theory and physical education praxis? *Physical Education & Sport Pedagogy*. doi:10.1080/17408980902791586.

Renshaw, I., Davids, K., & Savelsbergh, G. J. P. (2010). *Motor Learning in Practice: A Constraints-Led Approach* (1st ed.). London: Routledge.

Richardson, M. J., Garcia, R. L., Frank, T. D., Gergor, M., & Marsh, K. L. (2012). Measuring group synchrony: a cluster-phase method for analyzingmultivariate movement time-series. *Frontiers in Psychology, 3*, 1-10.

Seifert, L., Komar, J., Araújo, D., & Davids, K. (2016). Review article: Neurobiological degeneracy: A key property for functional adaptations of perception and action to constraints. In (Vol. 69, pp. 159).

Silva, P., Aguiar, P., Duarte, R., Davids, K., Araujo, D., & Garganta, J. (2014c). Effects of Pitch Size and Skill Level on Tactical Behaviours of Association Football Players During Small-Sided and Conditioned Games. *International Journal of Sports Science & Coaching, 9*(5), 993-1006. doi:10.1260/1747-9541.9.5.993

Silva, P., Chung, D., Carvalho, T., Cardoso, T., Davids, K., Araujo, D., & Garganta, J. (2016). Practice effects on intra-team synergies in football teams. *Human Movement Science, 46*, 39-51. doi:10.1016/j.humov.2015.11.017

Silva, P., Chung, D., Carvalho, T., Cardoso, T., Davids, K., Araújo, D., & Garganta, J. (2016a). Practice effects on intra-team synergies in football teams. *Human Movement Science, 46*, 36-51.

Silva, P., Duarte, R., Esteves, P., Travassos, B., & Vilar, L. (2016). Application of entropy measures to analysis of performance in team sports. *International Journal of Performance Analysis in Sport, 16*, 753-768.

Silva, P., Duarte, R., Sampaio, J., Aguiar, P., Davids, K., Araujo, D., & Garganta, J. (2014a). Field dimension and skill level constrain team tactical behaviours in small-sided and conditioned games in football. *Journal of Sports Sciences, 32*(20), 1888-1896.

Silva, P., Esteves, P., Correia, V., Davids, K., Araujo, D., & Garganta, J. (2015). Effects of manipulations of player numbers vs. field dimensions on inter-individual coordination during small-sided games in youth football. *International Journal of Performance Analysis in Sport, 15*, 641-659.

Silva, P., Garganta, J., Araújo, D., Davids, K., & Aguiar, P. (2013). Shared knowledge or shared affordances? Insights from an ecological dynamics approach to team coordination in sports. *Sports Medicine, 43*, 765-772.

Silva, P., Travassos, B., Vilar, L., Aguiar, P., Davids, K., Araújo, D., & Garganta, J. (2014b). Numerical Relations and Skill Level Constrain Co-Adaptive Behaviors of Agents in Sports Teams. *PLoS ONE, 9*(9). Retrieved from

Simmons, J., Nelson, L., & Simonsohn, U. (2011). False-positive psychology: undisclosed flexibility in data collection and analysis allows presenting anything as significant. *Psychological Science*, *22*(11), 1359-1366.

Simonsohn, U., Nelson, L. D., & Simmons, J. P. (2014). P-curve: a key to the file-drawer. *Journal of Experimental Psychology: General, 143*, 534-547. doi:10.1037/a0033242

Tan, T. Y. H., Chow, J. Y., Duarte, R., & Davids, K. (2017). Manipulating task constraints shapes emergence of herding tendencies in team games performance. *International Journal of Sports Science and Coaching, 12*(5), 595-602. doi:10.1177/1747954117727661

Travassos, B., Araújo, D., Davids, K., O'Hara, K., Leitão, J., & Cortinhas, A. (2013). Expertise effects on decision-making in sport are constrained by requisite response behaviours e A meta-analysis. *Psychology of Sport and Exercise, 14*, 211-219.

Travassos, B., Bourbousson, J., Esteves, P. T., Marcelino, R., Pacheco, M., & Davids, K. (2016). Adaptive behaviours of attacking futsal teams to opposition defensive formations. *Human Movement Science, 47*, 98-105.

Travassos, B., Coutinho, D., Gonçalves, B., Pedroso, P., & Sampaio, J. (2018). Effects of manipulating the number of targets in U9, U11, U15 and U17 futsal players' tactical behaviour. *Human Movement Science, 61*, 19-26. doi:10.1016/j.humov.2018.06.017

Travassos, B., Duarte, R., Vilar, L., Davids, K., & Araújo, D. (2012d). Practice task design in team sports: Representativeness enhanced by increasing opportunities for action. *Journal of Sports Sciences, 30*(13), 1447-1454.

Travassos, B., Vilar, L., Araújo, D., & McGarry, T. (2014b). Tactical performance changes with equal vs unequal numbers of players in small-sided football games. *International Journal of Performance Analysis in Sport, 14*(2), 594-605.

Vilar, L., Araujo, D., Davids, K., Correia, V., & Esteves, P. T. (2013). Spatial-temporal constraints on decision-making during shooting performance in the team sport of futsal. *Journal of Sports Sciences, 31*(8), 840-846. doi:10.1080/02640414.2012.753155

Vilar, L., Araújo, D., Davids, K., Travassos, B., Duarte, R., & Parreira, J. (2014b). Interpersonal coordination tendencies supporting the creation/ prevention of goal scoring opportunities in futsal. *European Journal of Sport Science, 14*(1), 28-35.