ALTERNATIVE SEAT DESIGNS
A Systematic Review of Controlled Trials

By Ahmed Radwan, Jessica Hall, Ariana Pajazetovic, Owen Gillam and Duane Carpenter

LOW BACK PAIN (LBP) HAS BECOME A COMMON CAUSE OF PAIN and disability in the U.S., especially among office workers (Janwantanakul, Pensri, Mookay, et al., 2011). Not only does office work leave an individual inactive, but also, as time progresses, inadequate desk and chair ergonomics, as well as other factors can lead to fatigued muscles, poor posture and pain (Cho, Freivalds & Rovniak, 2017; Janwantanakul, et al., 2011). Over time, this disability can affect overall performance and has the potential to result in lost work hours (Ramdan, Hashim, Kamat, et al., 2014). If this condition is not treated properly or if the underlying cause is not addressed, it often leads to chronic LBP (Petit, Fouquet & Roquelaure, 2015). In fact, approximately 73% of individuals with LBP still have symptoms 1 year later (Carragee, 2005).

Depending on the severity or chronicity of LBP, medical treatment varies. The average cost per patient for a period of 12 months with LBP is approximately $2,380 but may exceed $76,080 if the severity and longevity of the LBP has progressed to the point of surgical intervention (Stewart, Yan, Boscarino, et al., 2015).

KEY TAKEAWAYS
- **Alternative seat designs claim to improve posture, performance and activity, but supporting research is limited.**
- **This systematic review analyzes the effects of nontraditional alternative seat designs on productivity and complaints of office workers compared to standard office chairs.**
- **Researchers evaluated quality-controlled trials that compared different seating designs. The authors provide recommendations based on the conclusions of the analysis.**

A solution to this expensive impairment associated with sedentary seated occupations is alternative ergonomic seat designs. Typically, an ergonomic seat design incorporates the appropriate seat height, depth, width, backrest dimensions, backrest angle, seat angle, armrests, legroom and the seat surface (Pheasant & Haslegrave, 2005). More recently, it is believed that constructing a chair to incorporate dynamic movement with the attributes noted may further improve the ergonomic design (Jackson, Banerjee-Guénette, Gregory, et al., 2013; Pheasant & Haslegrave, 2005).

These dynamic chairs encourage movement, and it is believed that this encouraged motion releases muscle tension, improves endurance and posture, and relieves spinal compression, all of which are musculoskeletal states that have the potential to lead to LBP (Jackson, et al., 2013; Pheasant & Haslegrave, 2005). Some examples of ergonomic seats include a standard or adapted stability ball, kneeling chairs and stand up stools (Al-Eisa, Buragadda & Melam, 2013; Jackson, et al., 2013; Pynt, 2013). Each is comprised of vastly different designs, with various features that the manufacturers claim alleviate complications of LBP.

These benefits of alternative ergonomic designs for an office chair provide stark contrast to the consequence of the standard office chair designs, which encourage static loading by placing the pelvis in a posterior pelvic tilt, putting the individual at risk for posterior herniation of the nucleus pulposus (Jackson, et al., 2013).

Ergonomically, it is important to understand the benefits and pitfalls of each available alternative or ergonomic seat design to better prevent workplace losses associated with LBP. If employers and ergonomists can modify a workstation to prevent injuries from occurring, prevention of work-related musculoskeletal disorders is possible (Vieira, Svoboda, Belniak, et al., 2016). However, due to the overwhelming number of alternative or ergonomic seat designs, and individual studies often proving each one's superiority over other alternatives, it is difficult to determine which chair would most effectively result in decreased LBP and increased productivity in office workers. Thus, the purpose of this systematic review is to consolidate best available evidence and determine the efficacy and clinical relevance of alternative ergonomic seat designs in reducing physical and mental stress, and improving productivity among office workers.

Methods

Inclusion Criteria

Articles were deemed eligible if they met the following inclusion criteria:

- a controlled trial that compares an alternative ergonomic seat to a standardized office chair;
- peer reviewed and published in English between Jan. 1, 2009, and Jan. 1, 2018;

•participants were at least age 18;
•the study focused on an office environment;
•outcome measures comprised some combination of discomfort, fatigue, pain, satisfaction and productivity.

Search Strategy

The researchers searched the following electronic databases for relevant controlled trials: PubMed, ScienceDirect, Google Scholar, and the Cumulative Index of Nursing and Allied Health Literature database (CINAHL). Keywords used were *seat design*, *ergonomics*, *alternative designs*, *office workers*, *pain*, *low back*, *discomfort*, *fatigue* and *productivity*. Two independent searchers performed the search process for each database using the same keywords and keyword combinations. In case of a discrepancy of findings between the searchers, a third independent reader was involved to resolve any disputes and contradictions.

Once articles met the inclusion criteria and were agreed upon by the three readers, a full version of the article was retrieved and the methodological quality of the 16 included articles was assessed by two independent readers, as well as a third to resolve any disputes in quality scores between the two raters. Figure 1 shows the process used for article inclusion and exclusion.

Methodological Quality

Researchers assessed methodological quality using both the Cochrane risk of bias (ROB) tool and the Physiotherapy Evidence Database (PEDro) scale. The ROB tool assesses six domains of bias including selection, performance, detection, attrition, reporting and other. For each domain, a clear "yes," "no" or "unclear" criteria is provided with room allocated to denote sources with paragraphed information or quotes. Sources of bias are assigned an overall high risk (if a single "no" answer was issued to any of the questions), low risk (if all answers were issued a "yes") or unclear risk (if one question was answered with an "unclear" as an option while the rest of the questions had a "yes"), based on researcher judgment and criteria provided in the Cochrane handbook (Higgins, Altman, Gøtzsche, et al., 2011). Studies have found that the ROB has low reliability, but intensive ROB tool training may provide mitigating effects by decreasing between-group variations in assessment findings (da Costa, Beckett, Diaz, et al., 2017).

The PEDro scale utilizes 11 items to assess the external validity, internal validity and interpretability of studies in terms of allocation, randomization, key outcomes, blinding, intention to treat and statistical comparisons. Using items 2 through 11, the sum of "yes" responses creates a score of zero to 10, with zero representing the lowest quality and 10 representing the highest. The reliability of the PEDro scale in evaluating randomized control trials is deemed fair to good, with individual questions ranging between fair or moderate to substantial (Maher, Sherrington, Herbert, et al., 2003). Rasch analysis results identified the PEDro scale to be a valid measure of methodological assessment that can be confidently utilized by clinicians and researchers (de Morton, 2009).

Results

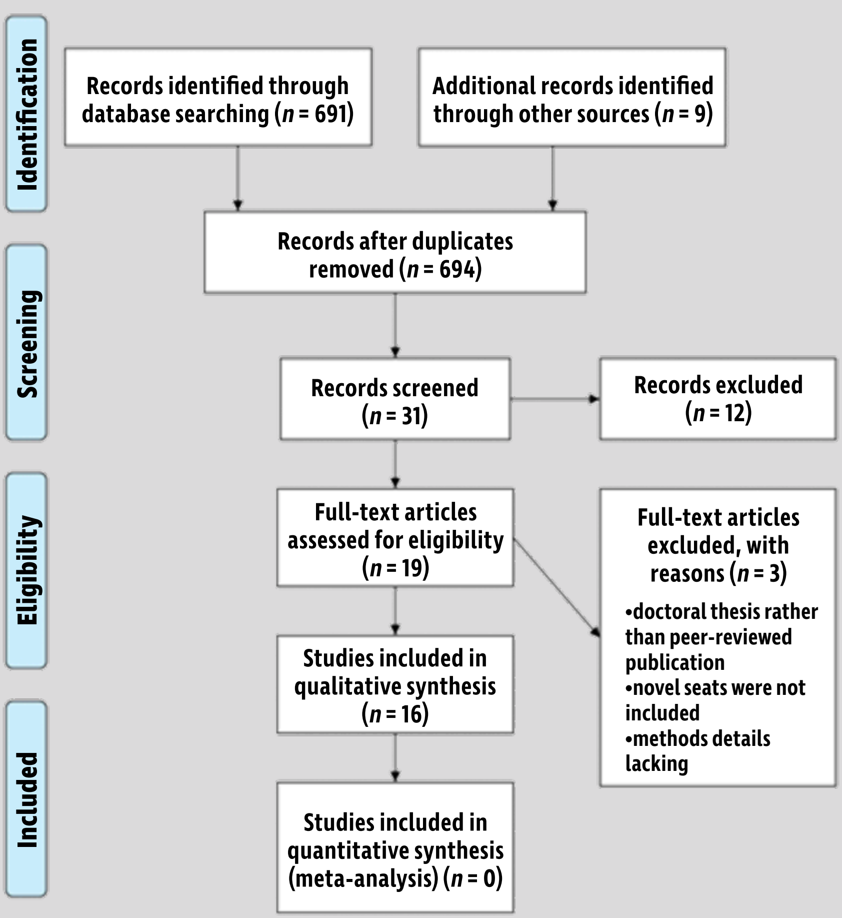
Results of this systematic review are summarized in table format to facilitate reading. Table 1 summarizes included article methodology and findings. Table 2 (p. 42) details information about methodological quality of each article represented by their PEDro scores. Table 3 (p. 42) identifies risk of bias assessment for each article.

Discussion

The purpose of this systematic review is to appraise and analyze the most recent available evidence about the effects of alternative seat designs on discomfort and productivity among office workers. The acceptance and use of ergonomic seat designs and chair systems as substitutes

FIGURE 1
PROCESS OF ARTICLE INCLUSION

PRISMA chart showing the process of article inclusion and exclusion.



Note. Adapted from "Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement," by D. Moher, A. Liberati, J. Tetzlaff, et al., 2009, *PLoS Medicine, 6*(7), e1000097.

TABLE 1

SUMMARY OF INCLUDED ARTICLES

Authors	Participant demographics	Intervention	Authors' conclusion
Articles about stools and kneelers			
Annetts, et al., 2012	14 subjects (6 M/8 F) Age: 20 to 23 (mean 21.1 years)	Subjects randomly used each of four different chairs for an 8-minute period: 3 minutes to adjust chair/workstation; 5-minute typing task.	No chair consistently yielded an ideal posture and all chairs produced lordotic posture. However, saddle stool is the most favorable overall chair for lumbopelvic and cervical regions. As joint angle changes in one region affect the remainder of the spine, chair selection must be based on individual need.
Grooten, et al., 2013	13 subjects (5 M/8 F) Age: 26.5 ± 9	Subjects performed 5-minute typing task with data recorded in final 3 minutes for each of five conditions: unstable BackApp stool; stable BackApp stool; saddle seat stool; conventional office chair; standing.	Unstable BackApp stool produced postural sway and muscle activation most like the standing condition. Conventional office chair produced the most postural sway and back muscle activation, while saddle stool produced the least muscle activation of all conditions.
O'Keefe, et al., 2013	21 subjects (6 M/15 F) Age: 22.1 ± 3.2	Subjects completed 1-hour typing task in both BackApp chair and standard office chair in a single session.	Significantly higher LBP in standard office chair at both 45- and 60-minute marks compared to BackApp chair.
O'Sullivan, et al., 2012a	12 subjects (5 M/7 F) Age: 23.3 ± 3.6	Subjects typed the same piece of literature placed on a stand next to a laptop for 10 minutes in BackApp chair and standard backless office chair.	Subjects displayed significantly less lumbar flexion and less lumbar muscle activation in BackApp chair compared to backless office chair.
O'Sullivan, et al., 2012b	12 subjects (5 M/7 F) Age: 23.3 ± 3.6	Using manual and verbal techniques, subjects were positioned into neutral sitting posture, which they maintained for 1 minute in both BackApp chair and standard office backless chair.	Overall posture in neutral sitting did not change between chairs, nor did perceived level of effort to maintain seated position show a significant difference.
Synnott, et al., 2017	15 subjects (9 M/6 F) Age: 24 (18 to 55)	Subjects watched a movie for 1 hour in both dynamic forward-inclined saddle (BackApp) chair and standard office chair.	Energy expenditure, MET values and overall body discomfort were significantly greater in BackApp chair compared to standard office chair.
Articles about dynamic chair seating option			
Ellegast, et al., 2012	Laboratory study 10 subjects (5 M/5 F) Age: M: 34.8 (12.7); F: 35.2 (12.3)	On each of 2 days, subjects performed seven office-related tasks for 100 minutes on four alternative and one standard office chair.	Addition of dynamic elements between chairs did not have a significant effect on muscle activation, postures, joint angles.
Groenesteijn, et al., 2012	12 subjects (4 M/8 F) Age: M: 35.3 (7.5); F: 36.1 (7.8)	Subjects performed nonstandardized daily tasks of computer work, telephoning, paperwork and conversing for 1 week in three conditions of dynamic seating.	If office workers are highly specialized, then a specific alternative chair is appropriate. Otherwise a standard office chair will provide the best mean comfort.
Articles about exercise balls and framed stability balls			
Al-Eisa, et al., 2013	40 subjects (40 F) Age: 20 ± 2	During weeks 1 to 4, subjects attended three lectures per week seated in classroom chairs. In weeks 5 to 8, students attended three lectures per week seated on a Swiss ball. Each lecture was 100 minutes with a 10-minute break.	Both performance and sitting discomfort in neck, shoulder and lower back improved significantly while sitting on Swiss balls compared to typical classroom chairs.
Elliott, et al., 2016	90 subjects (17 M/73 F) Age: 18 to 63	Participants randomly assigned to an intervention (ball sitting) or control group (standard office chair) for a 24-week study.	Stability ball use had significant impact on LBP and disability of users. However, using the ball led to significant increase in core endurance.
Jackson, et al., 2013	12 matched subjects (6 M/6 F) Age: M 24.5 ± 3.7; F 23.2 ± 3.9	One individual from each pair randomly assigned to stability ball on four-point base and casters with accommodation, or standard office chair.	Women indicated less perceived discomfort after accommodation training while men did not. No significant difference in muscle activity and posture between conditions.
Kingma & van Dieën, 2009	10 subjects (10 F) Age: 21.7 ± 2.6	Subjects performed 1-hour typing task in two conditions: on stability ball; and on office chair with armrests. Conditions performed on separate days at same time of day.	Stability ball required less frequent, but larger postural corrections with no significant difference in thoracic muscle activation. Spinal shrinkage significantly increased in 1 hour on stability ball.
Schult, et al., 2013	193 subjects (29 M/164 F) Age: 18 to 55+	Subjects performed nonstandardized daily tasks on each of three chairs: stability ball; stability ball chair; and standard office chair. Subjects used each chair for 1 month in nonrandomized order.	All chairs deemed safe. Pain decreased with short-term use throughout the day with alternative chairs versus standard. Stability ball and stability ball chairs produced similar comfort ratings. Stability balls significantly improved perceived posture and energy over standard chair, while stability ball chair significantly improved perceived posture and balance.
Articles about cycling and treadmill stations			
Cho, et al., 2017	30 subjects (15 M/15 F) Age: 23.1 ± 4.19	Subjects performed 10-minute reading comprehension and typing task in three randomly assigned conditions (no cycling; 10 W; 25 W) and one self-selected pace on DeskCycle.	Cycling condition did not significantly affect comprehension time, while typing accuracy was inversely correlated to cycling speed.
Commissaris, et al., 2014	15 subjects (7 M/8 F) Age: 29 (12)	Participants completed 5 minutes each of a typing, reading and mouse dexterity task; 3 minutes of a telephone task; and 6 to 8 minutes of a task assessing attention using sit-stand office desk (both sitting and standing), treadmill desk at 2.5 km/h, semirecumbent elliptical trainer at 17 W, and bicycle ergometer at 25% and 40% of participants' heart rate reserve.	No significant difference in reading speed and accuracy between conditions. Treadmill caused significant decline in typing speed, but all conditions except standing created significant decline in mouse task performance and telephoning quality. Similarly, working memory performance decreased significantly while cycling at 40% heart rate reserve.
Straker, et al., 2009	Office workers: 30 subjects (14 M/16 F) Age: 22 to 64	In a single session, subjects completed 3-minute typing task, four sets of 20 mouse-pointing trials, and 2-minute combined typing and mousing task in each of sitting, standing, cycling (5 W; 30 W), and walking (1.6 km/h; 3.2 km/h).	Subjects showed significantly increased errors and decreased speed while typing in walking conditions versus sitting.

Note. M = male; F = female.

TABLE 2

PEDro SCORES FOR EACH ARTICLE

Article	Eligibility specified (not included in total score)	Subjects randomly allocated	Allocation concealed	Groups similar	Blinding: Subjects	Blinding: Therapists	Blinding: Assessors	> 85% measured	All treated/controlled	Between group	Point and variability	Total score
Al-Eisa, et al., 2013	x			x				x	x	x	x	5/10
Annetts, et al., 2012	x			x				x	x	x	x	5/10
Cho, et al., 2017	x			x				x	x	x	x	5/10
Commissaris, et al., 2014	x			x				x	x	x	x	5/10
Ellegast, et al., 2012				x				x	x	x	x	5/10
Elliott, et al., 2016	x	x		x				x		x		4/10
Groenesteijn, et al., 2012				x				x	x	x	x	5/10
Grooten, et al., 2013				x				x	x	x	x	5/10
Jackson, et al., 2013	x			x				x	x	x	x	5/10
Kingma & van Dieën, 2009				x				x	x	x	x	5/10
O'Keeffe, et al., 2013	x	x		x				x	x	x	x	6/10
O'Sullivan, et al., 2012a	x			x				x	x	x	x	5/10
O'Sullivan, et al., 2012b	x			x				x	x	x	x	5/10
Schult, et al., 2013				x						x	x	3/10
Straker, et al., 2009	x			x				x	x	x	x	5/10
Synnott, et al., 2017	x	x	x	x				x	x	x	x	7/10

for the traditional office chair has grown exponentially in recent years, as users adopt a more active approach to sitting (Annetts, Coales, Colville, et al., 2012). Dynamic seating systems can alleviate the debilitating musculoskeletal system disorders sequella to sustained positioning in traditional static designs (Alnaser & Wughalter, 2009). This review included a selection of the most popular dynamic seating options such as stability balls, stools, saddle seats, kneelers, treadmill desks, semirecumbent elliptical trainers, bicycle ergometers, chairs whose seat pans rotated constantly on a 16° arc with an electromotor, chairs with a suspension system style seat pan, chairs with a swing style seat pan, and chairs with the seat pan placed on a universal joint to simulate sitting on a ball. This review compiled the benefits and disadvantages of these seating systems recorded by researchers, appraised the value of their evidence and provided the conclusions for end-state users in one location with a backdrop of musculoskeletal anatomy and proper ergonomic principles for context.

Demographics

Initial search parameters for relevant research for this systematic review focused on articles whose subjects were office workers over age 18 and especially those experiencing LBP. Overall, there were 442 total subjects, with 325 female subjects and 117 male subjects (2.79:1

TABLE 3

ROB SCORES FOR EACH ARTICLE

Article	Sequence generation	Allocation concealment	Blinding appropriately	Incomplete outcome data	Selective reporting	Other sources of bias	Total risk
Al-Eisa, et al., 2013	No	Unclear	Unclear	Unclear	Unclear	No	High
Annetts, et al., 2012	Unclear	No	No	Yes	Unclear	Yes	High
Cho, et al., 2017	No	No	Unclear	Yes	Unclear	Yes	High
Commissaris, et al., 2014	No	No	No	Yes	Unclear	Yes	High
Ellegast, et al., 2012	No	No	No	Yes	Unclear	Yes	High
Elliott, et al., 2016	No	No	No	Yes	Unclear	Yes	High
Groenesteijn, et al., 2012	No	No	No	Yes	Unclear	Yes	High
Grooten, et al., 2013	No	No	No	Yes	Unclear	Yes	High
Jackson, et al., 2013	No	No	No	Yes	Yes	No	High
Kingma & van Dieën, 2009	No	No	No	Yes	Unclear	No	High
O'Keeffe, et al., 2013	No	No	No	Yes	Yes	No	High
O'Sullivan, et al., 2012a	No	No	No	Yes	Yes	Yes	High
O'Sullivan, et al., 2012b	No	Yes	No	Yes	Unclear	Yes	High
Schult, et al., 2013	No	No	No	No	Yes	No	High
Straker, et al., 2009	No	No	No	Yes	Yes	No	High
Synnott, et al., 2017	No	Yes	No	Yes	Yes	Yes	High

female to male ratio). Studies in which female subjects outnumber male subjects is a common trend in this systematic review and, in fact, several studies included only female subjects and lack a comparison between genders (Al-Eisa, et al., 2013; Kingma & van Dieën, 2009). This is considered a limitation in this review and readers must be aware that the difference in anatomical and physiological functions of both genders may impact the results of this review. Future systematic reviews with balanced samples (in terms of gender) should be conducted to validate the findings of this review.

Meeting the goal of this systematic review, the average age of included subjects is 28. Additionally, participants were primarily students, faculty members and office workers, which are professions associated with seated desk work and computer use. However, despite the included research studying the desired population, threats to external validity exist within the demographics. For example, several studies do not report a mean value or standard deviation for subject age, but instead simply provide a range such as age 18 to 55 (Elliott, Marshall, Lake, et al., 2016; Schult, Awosika, Schmunk, et al., 2013; Straker, Levine & Campbell, 2009). Although subjects included office workers and similar professions, the time subjects typically spend seated at a desk may vary widely and is not enumerated.

Methodological Quality of Reviewed Articles

Researchers employed the PEDro scale and ROB assessment tools to evaluate article quality. The mean PEDro score across the 16 articles was 5/10, with a range 3/10 to 5/10. Trends that resulted in lower scoring included failure to perform random allocation, concealment of treatment, blinding of subjects, participants or assessors involved, as well as intention to treat analysis in case of reported attrition. Similar trends, resulting in a higher risk of bias, presented during analysis with the ROB assessment. Most articles lacked sequence generation, allocation concealment and blinding of participants, personnel and outcome assessors. This resulted in a high risk of bias score for all 16 articles.

Benefits of Traditional Chair

All studies included in this systematic review compared ergonomic designs to a standard office chair. A standard office chair is the typical seat design used in most environments such as office workstations and universities (Al-Eisa, et al., 2013; Grooten, Conradsson, Äng, et al., 2013). This design consists of adjustable seat height and seat angles, and a five-star castor base, with its popularity based primarily on convenience of cost to employers (Alnaser & Wughalter, 2009).

Traditional chairs provide benefits in addition to affordability. In this systematic review, three articles found superior ratings of comfort and energy expenditure for standard office chairs over their ergonomic counterparts (Groenesteijn, Ellegast, Keller, et al., 2012; Kingma & van Dieën, 2009; Synnott, Dankaerts, Seghers, et al., 2017). According to Groenesteijn, et al. (2012), if workers' duties require a varying assortment of office tasks, the standard office chair provides higher mean comfort ratings. A study by Beers, Roemmich, Epstein, et al. (2008), supports this finding, reporting that subjects showed a preference for standard office chairs rather than an alternative seat design during word processing tasks. Furthermore, Synnott, et al. (2017), determined that energy expenditure, metabolic equivalent of task (MET) values indicating oxygen needs and overall body discomfort are significantly greater while using the BackApp chair compared to a standard office chair. Gadge and Innes (2007) reached a similar conclusion with the Bambach saddle seat, where findings demonstrate increased discomfort, especially in the lower limbs, compared to the standard office chair. Still, ergonomists must remember that ergonomic chairs are still novel, and users often have little or no experience with them. Habituation and unfamiliarity with a new chair may influence a less than favorable response to ergonomic designs (Synnott, et al., 2017).

Contradicting these findings, three other studies included in this systematic review found evidence favoring the alternative seat designs as compared to a typical seating system (O'Keeffe, Dankaerts, O'Sullivan, et al., 2013; O'Sullivan, McCarthy, White, et al., 2012a; Synnott, et al., 2017). O'Sullivan, McCarthy, White, et al. (2012b), report that during a brief typing task, participants displayed less lumbar flexion as well as less lumbar muscle activation on the BackApp chair compared to a backless standard office chair. In addition, Grooten, et al. (2013), found that conventional office chairs cause the most postural sway and back muscle activation. Both studies suggest that the standard office chair does not best facilitate ideal posture in subjects. Similarly, O'Keeffe, et al. (2013), observed overall increase in discomfort when sitting on a standard chair with a backrest compared to the dynamic forward-inclined saddle chair while conducting general office tasks.

The contradiction in research findings may result from the researcher choice of subjects. O'Keeffe, et al. (2013), recruited a sample of convenience whose subjects had flexion-based LBP that was relieved through postures that anteriorly tilted the pelvic angle. A forward-inclined saddle chair would facilitate this movement, relieving LBP in these individuals. However, Synnot, et al. (2017), recruited pain-free subjects who would not have a bias for anterior pelvic tilt and preferred the familiar standard office chair. With limited research available in the field, ergonomists must remain diligent in assessing articles, as subject selection or seating familiarity may cause contradictory findings that would not exist if all variables were equal.

Benefits of Alternative Seat Designs

Saddle Chair

Two saddle design chairs are included in this systematic review: the BackApp and a standard saddle chair. The main difference between the two is the ability of the BackApp to become dynamic through an adjustment on the bottom of the chair where it is possible to set varying degrees of stability (O'Sullivan, et al., 2012a;b). Analysis of articles revealed that the BackApp, when compared to a standard office chair, provides a more neutral sitting posture while promoting an anteriorly tilted pelvis (Grooten, et al., 2013; O'Sullivan, et al., 2012b), as well as reducing overall body discomfort and LBP (O'Keeffe, et al., 2013).

The average saddle seat performed analogously to the BackApp chair. Grooten, et al. (2013), determined that the saddle seat produces the least muscle activation and the most neutral sitting posture in the lumbar region. The study by Annetts, et al. (2012), agrees, determining that the saddle seat facilitates the closest ideal spinal posture in both the lumbopelvic and cervical regions.

Similarly, Gadge and Innes (2007) found that low-back discomfort was greater in a standard office chair as compared to a saddle seat; however perceived discomfort increased with time regardless of the seat being used. In that study, most of the re-

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Photos 1-4 (clockwise from top left): Examples of a saddle chair; a kneeler, a stability ball and a framed stability ball.

ported discomfort with the saddle seat was in the lower limb, hip or buttocks area. The variance in pressure resultant from the seat design may have caused a decrease in blood circulation resulting in discomfort for some. These authors also found that saddle seats create slightly negative or no effect on worker productivity, noting a trend of increased errors or decreased speed while utilizing the saddle chair.

Kneeler

The kneeler, although a novel and unique design, was evaluated in only one study included in this systematic review. It did not perform well compared to other ergonomic designs or even to a standard backless office chair. Annetts, et al. (2012), determined use of the kneeler results in poor posture with excessive capital/cervical flexion and lumbar lordosis. While a neutral spinal posture is considered ideal, the kneeler chair forces spinal segments into undesirable end ranges (Annetts, et al., 2012). Although evidence is limited, the kneeler appears to be a poor alternative chair design.

When comparing the results of Annetts, et al. (2012), to other research findings, there are varying opinions. For example, the kneeler seat improved lumbar lordosis in a less significant manner than that of a standard office chair, as determined by Vaucher, Isner-Horobeti, Demattei, et al. (2015). Bettany-Saltikov, Warren, Jobson, et al. (2008), found conflicting results to that of Vaucher, et al. (2015), noting that an ergonomically designed kneeling chair set to greater than 20° of inclination, maintains a better lumbar curvature than that of an individual who is standing. Note that Bettany-Saltikov, et al. (2008), did not have study participants perform any office work. Instead, only spinal curvatures were measured in standing or seated positions on either a backless office chair or a kneeler, which could account for some of the variation found between the results of that study and those within this systematic review.

Stability Ball

Stability balls, or exercise balls, are a common alternative seat design for office workspaces. Popularity of this alternative seat design is not undeserved, as evidence suggests that users perceive that their posture as well as their energy levels improve when using stability balls compared to a standard office chair (Schult, et al., 2013).

However, evidence is not entirely unanimous, as some research suggests that no significant difference exists in muscle activation or posture between the use of a stability ball and a standard office chair (Groenesteijn, et al., 2012). Note that Groenesteijn, et al. (2012), did not evaluate an actual stability ball, but rather a standard office chair that pivoted on a universal joint. While attempting to blind subjects or prevent bias, the researches eliminated essential structural differences in the seat designs, comparing only the postural support available with each seating option. This would suggest that the greatest effect of the stability ball is not its tendency to tilt and roll, but rather the postural support, or lack thereof, that it provides the user.

This contention is further evidenced by measuring postural muscle activation with surface EMGs, showing significantly decreased frequency but increased amplitude in muscle activation while sitting on a stability ball compared to a standard office chair (Kingma & van Dieën, 2009). One may conclude that the critical trait of the stability ball is the lack of support for a typical seated position. The user is required to assume a more "active" seated position, with a typically increased anterior tilt of the pelvis. This seated position may in fact be a more stable, balanced condition requiring little correction. However, when a user exceeds the limits of his/her balance, larger corrective postural muscle inputs are required as compared to the smaller, more frequent muscle activations seen in the standard office chair.

Evidence also supports the claim that stability balls reduce pain and discomfort in users. Even short-term use of stability balls throughout the day are found to significantly reduce pain (Schult, et al., 2013). This may include pain in the neck, shoulder or low back (Al-Eisa, et al., 2013). Even office chairs that simulate a stability ball using a universal joint may reduce pain during certain desk work (Groenesteijn, et al., 2012). However, this prospective benefit requires further research, as studies also suggest there is no significant reduction in LBP or disability after using a stability ball (Elliott, et al., 2016). In fact, after 1 hour of sitting on a stability ball, one study noted a significant increase in spinal shrinkage compared to a standard office chair (Kingma & van Dieën, 2009). Increased or excessive spinal shrinkage may impinge spinal nerve roots exiting at each of the vertebrae, which may result in sharp, shooting pains, radiating into the extremities. Further research is indicated to solidify evidentiary support on the amount and location of pain reduction using the stability ball.

Ancillary to pain and postural improvements, an essential quality of chairs in a work environment is the effect they pose on employee performance. Productivity and quality are essential in the work environment, and evidence supports beneficial effects from stability ball use. Performance, measured via a problem-based learning scale in the categories of participation, comprehension, cooperation and knowledge, significantly increased in subjects using a stability ball versus a standard chair (Al-Eisa, et al., 2013). Muscular endurance, especially in the sagittal plane, also showed significant increases. Improved muscular endurance not only benefits physical health, but also reduces fatigue, improving work performance and quality.

Framed Stability Ball

Framed stability balls are a common variant of the stability ball. Rather than a standard ball with three degrees of freedom, a framed stability ball is fixed in a rigid frame. The tilt and rolling movement of a stability ball is sacrificed for structural stability, while the underlying structural design and requirement for an active seated posture are maintained. As a result, postural muscle activity shows no significant difference compared to a standard stability ball. For subjects using a framed stability ball, the rigid stabilization resulted in subjects perceiving improved posture and balance (Schult, et al., 2013). As posture improves, and a more stable and balanced seated spinal position is assumed, pain decreases significantly compared to an office chair (Schult, et al., 2013).

Desk Bike

More office spaces are accommodating active office workspaces to promote employee health while maintaining or reducing downtime. As a result, desk bikes or bicycle ergometers have entered the workplace. Instead of focusing on posture, desk cycles focus on physical activity to promote fitness through physical exertion. Desk bikes achieve this goal, as one study shows perceived exertion increases as cycling speed increases (Cho, et al., 2017).

However, although employee health is an important consideration, manufacturing companies must worry about productivity and quality of work performance. As desk bicycles require more of a physical and cognitive effort to maintain activity levels than other active chair designs, consequent deficits in performance are expected. For example, typing speed may respond with a significant inverse relationship to cycling speed (Cho, et al., 2017), although this is not definitively proven (Commissaris, Könemann, Hiemstra-van Mastrigt, et al., 2014). As more effort is put into cycling, employees may type slower and with more errors, reducing the quality and efficiency of their work. Mouse task performance and telephoning quality also show significant inverse relationships to cycling speed (Commissaris, et al., 2014). Even working memory may experience deficits when cycling speed approaches an exertion level commensurate with 40% of an individual's heart rate reserve. These performance restrictions are important for employers and employees to consider before deciding to use desk bikes at work.

Treadmill

As one might expect, with dynamic movement of the lower body on a treadmill and no segment stabilized, as in a desk cycle, work performance deteriorates. Commissaris, et al. (2014), found that even walking at a pace of 2.5 km/h resulted in statistically significant reduction in mouse reaction speed and accuracy, and in typing speed over a seated condition. However, typing accuracy, performance on a reading task and an assessment of cognitive function did not decrease significantly on a treadmill.

Similarly, Kravitz (2016) determined that treadmill speeds of 1 to 2 mph were capable of increasing energy expenditure by a minimum of 100 kcal per hour when compared to a standard office workstation. This can have a significant effect on an individual's body weight and daily activity levels, depending on the amount of time the individual can use such an active desk throughout the workday. In concordance with that, in a study by Tudor-Locke, Schuna, Frensham, et al. (2014), workers reported a self-perceived boost in creativity and advocated the benefits of breaking up the workday with the use of a treadmill desk setup. Thus, in certain environments where mousing or typing speed are not essential functions, a treadmill desk serves as an active alternative for the office workplace.

Conclusion

According to the current systematic review, the quality of the reviewed articles contributed moderate evidence toward choosing an ideal alternative seat option. The reviewed articles recommended that ergonomic stools produced appropriate lumbar and cervical posture while working. Also, use of stability balls and stability ball chairs may improve posture, energy and perceived balance. Finally, the use of active alternatives such as a desk cycle or treadmill increase exertion and activity levels but reduce accuracy of tasks (e.g, typing, mousing, telephoning, working memory) and that such adverse productivity may outweigh therapeutic benefits in a business environment.

The current moderate evidence in the literature (supporting the benefits of alternative chair designs in decreasing muscle activation, discomfort, improving posture, and positively affecting productivity) confirms the need for further high-quality research to compare and further analyze alternative chair designs and options. According to this review, the authors found that, at present, there is not a perfect single chair design that fits all needs, and that individuals must prioritize their requirements and individually select an office chair that fits most of their respective needs. Therefore, the authors strongly recommend the use of more than one seating option per office space and still following the current ergonomic consensus of mixing sitting with standing and walking to achieve the utmost benefit to office workers. **PSJ**

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Ahmed Radwan, Ph.D., M.Sc., M.B.A., PT, DPT, CPE, is a professor of physical therapy and chair of the Health Studies Department at Utica College. He is a founder and director of Utica College's Center for Ergonomics Analysis and Research. He has taught for more than 20 years with a focus on research, ergonomics, evidence-based practice, musculoskeletal rehabilitation and movement science. His research interests include ergonomics and biomechanical analysis of musculoskeletal problems. Radwan has published and presented more than 75 peer-reviewed publications, national and international presentations in the fields of ergonomics and motion analysis.

Jessica Hall, PT, DPT, is a physical therapist at MedStar Franklin Square Medical Center. She holds a Doctor of Physical Therapy and a bachelor's degree in Health Studies from Utica College, and participated in New York state's Health Quest internship program. Hall's commentary regarding the recovery of individuals with below-the-knee amputations has been published in American Journal of Physical Therapy.

Ariana Pajazetovic, PT, DPT, is a research assistant for a study involving athletes post ACL reconstruction, and a lab tutor for fellow physical therapy students. She holds a Doctor of Physical Therapy and a bachelor's degree in Health Studies from Utica College.

Owen Gillam, PT, DPT, holds a Doctor of Physical Therapy and a bachelor's degree in Health Studies from Utica College.

Duane Carpenter, PT, DPT, holds a Doctor of Physical Therapy from Utica College, and a B.S. in Mechanical Engineering from the U.S. Military Academy at West Point. He served in the U.S. Army as an officer and a UH-60 Blackhawk pilot.