A Trend Analysis of Dynamic Chair and Applied Technology

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Objective: The objective of this study was to define the Dynamic Sitting (DS) through trend analysis and research on the Dynamic Chair (DC) and applied technologies.

Background: The effects of changing posture on the human body have been studied to find out healthy sitting postures. It is believed that changing posture is effective in reducing disc pressure on spinal cord and preventing back pain and musculoskeletal disease. But, the definition of DS and trends of DC have not been researched yet. Therefore, trend analysis of DC and its applied technologies are required to define dynamic sitting posture.

Method: We researched the type of occupant postures from previous studies. And then, sitting behaviors were classified into three types; (1) sitting and standing, (2) working and studying, (3) taking a rest.

Results: Variety shapes of DC and applied technologies were found out. From the result, the trend of DC and applied technology were summarized from three perspectives; (1) changing the chair functions according to user's intention, (2) conversion of dynamic chair technologies to office chair mechanism, (3) enables the user to change their sitting posture without operating control device.

Conclusion: From this study, we defined dynamic sitting posture and analyzed the trend of DC and its applied technologies. This result might be used to develop an office chair for healthy sitting. But further investigation is required to figure out the technologies and functions for development of healthy chair.

Application: The results of the publishing trend analysis might help to determine design concept of office chair.

Keywords: Trend analysis, Dynamic chair, Sitting behavior, Office chair, Tilt mechanism

1. Introduction

As the office environment changes, the modern workers are sitting on a chair for more than 75% of their daily working hours and the importance of their sitting postures is being emphasized as such (Park et al., 2000). Until the 19th century, physiologists and orthopedists have considered it is the best sitting posture to keep the back, neck, and head upright, keep the thigh horizontal with the ground surface, and keep the calf at right angle as the best sitting posture (Karl, 2006). However, as the work environment changed a lot and there have been a lot of studies on the healthful sitting posture right in the modern society, the best sitting posture is also...
defined otherwise. When a human body sits on a chair, the pelvis rotates backwards by about 40° and the lumbar curvature changes from lordosis to kyphosis (Schoberth and Hegemann, 1962). This kyphotic posture raises the disc pressure and eventually causes back pain and disc herniation when this raised disc pressure is kept long (Schultz et al., 1982). In fact, long-term occupants have been reported to have the greatest discomfort at their lumbar parts (Martin and Lijan, 1997). But, there was another report which said such a discomfort could be reduced over a long time when fine and repeated movement is imposed on the lumbar vertebral column (Cammie et al., 2012). Encouraged by these studies, we are making efforts on developing the concept of ‘Dynamic Sitting’ to reduce the discomfort imposed on the lumbar part as well as the various dynamic chairs where the technology corresponding to the above concept is grafted. In this study, we are going to approach at the background of the appearance of dynamic chairs from the biomechanical viewpoint and look over their trend and applied technologies.

2. Definition of Dynamic Chair

2.1 Background of dynamic sitting

The dynamic sitting was born with the biomechanical background to relieve the discomfort of a human body during sitting. Most of the people who are complaining about their low back pain tend to maintain static posture for a long time without lumbar movement (Dankaerts et al., 2006, Scott et al., 2009, Margarita and Alvaro, 2002). Branton and Grayson (1967) observed the sitting posture of 45,000 people and insisted a chair should allow its users to change their postures at their discretion while Greil et al., (1997) observed the posture of occupants sitting in an office chair to find out they changed their postures 12 to 16 times for 5 hours. In other words, the occupants should be permitted to change their sitting postures regularly to keep healthful sitting posture. Changing the sitting posture regularly improves the oxygen flow under the skin to reduce disc contraction (Dieen et al., 2001) and reduce the lumbar pain (Reenalda et al., 2010). Furthermore, a research result was published which agreed that promoting the fine movement of spine will alter the muscular activation of trunk and contribute to disc pressure reduction (McGil et al., 2009) and thus reduce lumbar pain (Dieen et al., 2001).

2.2 Definition of dynamic sitting

Currently, a number of studies are under progress to figure out how a dynamic chair affects human bodies. However, the only thing about the dynamic chair revealed so far is that it is a kind of chair for promoting body movements during sitting. No consensus has been made about the pattern of dynamic sitting or chair requirements. Accordingly, we summarized the previous studies in which they claimed to support so-called dynamic chairs and used them for their experiment along with the study method of dynamic sitting for each study object and scope in Table 1.

<table>
<thead>
<tr>
<th>Author (Year)</th>
<th>Object</th>
<th>Scope</th>
<th>Methodology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keegan, J.J. (1953)</td>
<td>Chair</td>
<td>Seat Pan</td>
<td>Check how the lumbar looks differently and measure how much the muscle activation is relaxed according to trunk-thigh angle variation.</td>
</tr>
<tr>
<td>Andersson, B.J et al (1974)</td>
<td>Office chair</td>
<td>Armrest</td>
<td>Check how much the disc pressure and trapezius tension drop by using an armrest.</td>
</tr>
<tr>
<td></td>
<td>Office chair</td>
<td>Backrest, Lumbar Support</td>
<td>Check how much the disc pressure varies on the backrest angle and lumbar pad depth.</td>
</tr>
</tbody>
</table>
The concept of a dynamic chair can be variously defined as backrest and seat pan sloping (Dieen et al., 2001), rotation of seat pan (Deursen et al., 2000), forward sloping of seat pan (Roh et al., 2012), changing the depth of lumbar support (Tyson et al., 2003), and dynamic seat pan (Kingma and Dieen, 2009) such as the ball chair. As a common opinion in the literature, it can be defined as a chair that can support the occupants physically and technologically to reflect their behaviors.

### 3. Dynamic Chair

#### 3.1 Access to occupant behavior in dynamic sitting posture

An occupant sits on a chair, doing various things including not only computer work, reading, and writing but also dining and sleeping. Peter (2009), in his book, ‘Rethinking Sitting’, divided the sitting posture into 5 steps from lying posture to bent forward posture and defined each purpose like Figure 1. An occupant showed more precise and concentrated behavior with more tilted posture, and we can see the more leaning backward, the closer to resting.

![Figure 1. The occupant behavior for each type of sitting posture (Peter Opsvik, 2009)](http://jesk.or.kr)
The occupants are keeping the dynamic sitting posture by transforming their chairs according to the sitting purpose and target. Grandjean and Hünting (1977) studied the weight for each sitting position of an occupant during work, and the result according to the sitting position was 15% in the front, 52% in the middle, 33% in the back. And also, sitting behavior was 42% for leaning on the backrest, 40% for bending forward and putting both arms on the desk. According to the Solution Essay published by Hermanmiller Co. (2009), a professional office chair manufacturer, an occupant has 3 major sitting postures (reclined, upright, forward), but the forward posture was most popular accounting for 45.2% (Figure 2).

**Figure 2.** Sitting pattern and frequency (Hermanmiller Solution Essay, 2009)

In this study, we summarized sitting patterns and behaviors in Table 2 with reference to Solution Essay of Grandjean and Hünting (1977) and Hermanmiller Co. (2009) and Rethinking Sitting of Peter (2009) prior to investigating the trend of dynamic chair.

<table>
<thead>
<tr>
<th>Posture pattern</th>
<th>Occupant action</th>
<th>Occupant behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting down/standing up</td>
<td></td>
<td>Sits on a chair</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stands up from a chair</td>
</tr>
<tr>
<td>Forward sitting</td>
<td>Working and studying (computer work, reading, writing, meeting, etc.)</td>
<td>Types a keyboard</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Controls and clicks a mouse</td>
</tr>
<tr>
<td>Upright sitting</td>
<td></td>
<td>Watches a monitor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chats with the next person</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reads a book</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Writes something</td>
</tr>
<tr>
<td>Reclined sitting</td>
<td>Resting</td>
<td>Leans on a chair</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stretch legs with their bodies laid on a chair</td>
</tr>
</tbody>
</table>

The behaviors on a dynamic chair can be classified into sitting, standing-up, working, studying, and resting. Among those, computer work, reading, and writing were analyzed as the posture that workers are taking for the longest period, and those behaviors were expressed in various sitting postures. Using a keyboard or mouse, watching a monitor, reading a book, or writing were analyzed as the behaviors that shall be supported most positively. Most of these postures necessarily force the occupants to stare an object by bending their backs or lower their heads for a long time. These postures impose pressure on the spine, increasing back pain according to the analysis.
3.2 Dynamic chair trend

3.2.1 Sitting down and standing up

Sitting down on a chair or standing up from a chair is meant to impose a lot of load on the knee joint (Donna et al., 2007). Okamura, a professional office chair maker, launched an office chair which added a function of helping sitting-down and standing-up to the existing office chair. Okamura’s office chair brands, Luce and Leopard, enable sitting down and standing up effortlessly, benefit from the gas cylinder and robot control system with their seat pans inclined forward to minimize the load on the occupant’s knee joint. In particular, Leopard is applied robot mechatronics technology of OKI Co. to offer automatic control of the sitting posture from a comfortable leaning position to upright sitting position by sensing any postural change, whether it is the automatic sitting-down/standing-up posture or sitting posture (Figure 3).

![Figure 3. Example of a chair which supports sitting and standing-up (Left: Luce of Okamura, Right: Leopard of Okamura)](image)

3.2.2 Working and studying

① Backrest tilting

The backrest tilting motion is the major postural change of an office chair, transferring the load on the lumbar to the backrest to reduce the disc pressure. The reclining of the backrest contributes to diminishing the muscular activity (Donald et al., 1999) and the contact pressure on the hip (Gordon et al., 2006). Meanwhile, the reclined posture may have a fatal disadvantage to office workers. As for general office chairs, if their backrests are tilted, a human body generates rotation (pivoting) on the ankle, knee, and hip joint at the same time movements on the shoulder and the head backward, eventually hands recede from the work area (keyboard, mouse, etc) (Rani, 2004). Sato, a professional office chair maker, launched the Galileo model which forbids hands to recede from the work area as the seat pan moves forward to let the occupants continue their work with their backrest reclined.

![Figure 4. An example of the chair which allows occupant to continue work with the backrest reclined (Galileo and Sato)](image)
This office chair adopted Glide mechanism, a tilt mechanism, to be interlocked with back tilting and allow the seat pan to move forward (Figure 4). As a result, with the occupants’ hands maintaining a certain distance from the work area, they can distribute their body pressures with their backs leaned on the backrest to minimize the load on their lumbar disc.

2. Forward sloping seat pan

Forward tilting of seat pan to increase the angle between the thigh and the trunk was also proven effective for the increasing lumbar lordosis. Keegan (1953), in his study on the spine health depends on the angle between the thigh and the trunk, pointed out the lumbar lordosis is often caused by the posture in which the seat pan is tilted, the angle between the thigh and the trunk is 135°, and legs touch the ground surface. Mandal (1987) discovered the horse riding posture maintained the lumbar lordosis and tried to apply such a concept to chair technology (Figure 5). Bendix and Sørensen (1983) as well as Ravindra (1997) simultaneously reported the bigger the forward sloping angle of seat pan, the more the spine looks likely the lordosis.

Figure 5. An example of the chair where the riding posture is applied (Mandal, 1976)

Peter (2009) insisted in his writing, ‘Rethinking Sitting’, that a forward sloping chair may induce lumbar lordosis. However, because seat pan tilting causes forward sliding, he designed Balans Chair where shin pads were attached to minimize the forward sliding force (Figure 6). Thereafter, Peter Opsvik launched various Shin-Rest chairs.

Figure 6. An example of the forward sloping chair with shin pads (Balans Chair, Peter Opsvik)

In the meantime, a new chair has been launched that can tilt the seat pan forward through kinematic change of the tilt mechanism, not modifying the shape of the existing office chair. The core technology of this chair is using the control device to lift the rear side of seat pan partially. Both Aeron and H05 are able to tilt both the seat pan and the backrest wholly based on the link structure of the tilt mechanism. Sidiz in Korea launched a model, T50, which rotates the single shaft roller connected to the back...
side of the seat pan to elevate the rear part of seat pan and thus change the seat pan angle (Figure 7). However, such chairs have a disadvantage that we must control the forward tilting lever of the seat pan whenever we bend ourselves forward.

**Figure 7.** An example of the forward sloping chair for office use, Aeron (Herman Miller), H05 (HAG), and T50 series (Sidiz)

3. **Application of dynamic seat pan**

   The multi-degree of freedom of a seat pan is also popular as a postural change method. A dynamic seat pan can be rolled and pitched or translated horizontally depending on the force balance. This kind of posture is aimed at making a positive effort to keep the spine upright without posture collapse rather than making a comfortable posture, ultimately seeking for symmetrical development of the muscles around the lumbar. These chairs are shaped in such a manner that their seat pans looked like a ball to keep them in the dynamic state optimum for maintaining the right posture (Figure 8).

**Figure 8.** An example of the office chair having a dynamic seat pan, Wheelers Gym Ball Chair, Hustle Chair (Taesung Chairman), and Wobble Chair

In addition, some dynamic chairs look like an office chair. These chairs were based on the technology of inclining a seat pan freely in all directions by releasing the tilt-lock device. These chairs are designed to be good for spine health by allowing the lumbar and upper body exercise from time to time during work, and thus they are loved by women interested in beauty and exercise in their 20s or 30s as alternative fitness equipment.

4. **Body pressure distribution**

   While sitting crouched, occupants are destined to receive a significant pressure (50~100kgf) in the lumbar disc, resulting in the disc symptom (Baik, 1997). A chair with a chest support can transfer such an internal pressure to the front structure to reduce the burden on lumbar disc (Figure 9).
3.2.3 Resting

A dynamic chair should be used not only for working and studying but also for resting in some occasions. For effective weight distribution, the occupants must lean backrest backward to spread the lumbar pressure on the backrest and maximize the contact area with a human body. Once the backrest is leaned backward, the human body will receive less disc pressure, and the back muscle will be less activated (Andersson et al., 1974). Gravity Balans Chair of Peter Opsvik allows various postures from computer work to reading and even resting after lying backward, and one of its technological properties is that it enables various sitting postures with upper body movement without an additional tilting device. Besides, Zero Gravity Chair of Contra tilts our body wholly until we make a posture as if we were in a weightless state to minimize the force on the lumbar. Meanwhile, IN-710 of INNO Chair in Korea is an example of launching an office chair for simultaneous working and resting from inventing a new mechanism by allowing the conventional office chair tilted by 180° backward (Figure 10).

4. Considerations and Conclusion

According to this study, we can roughly divide the above-mentioned dynamic chair examples into 3 different dynamic sitting tendency.

First, a dynamic chair can be physically and structurally transformed to meet the purpose and demand of the occupants. It shall consider the process of ever-changing posture, not being focused on meeting the requirement of only a static posture. It must
be able to support all kinds of postures depending on user behavior including working, resting, and sitting-down/standing-up. For example, the chair in Figure 11, Multi Balans (1981), can maintain lumbar lordosis by tilting the seat pan forward, but it is designed for only a static posture, so it cannot be called a dynamic chair. On the other hand, the office chair based on the tilt mechanism can support various postures from the upright sitting posture to the reclined sitting posture, so it can be called a dynamic chair.

Figure 11. An example of the chair designed for one posture, Multi Balans (Peter Opsvik)

Second, it is worth paying attention to the realization of office chair based on various dynamic sitting functions. An office chair is generally composed of backrest, seat pan, armrest, and tilt mechanism. Being the key element of an office chair, the tilt mechanism changes the slope of backrest and seat pan to let the occupants change their postures and maintain the comfortable and healthful posture. The number of cases in which the dynamic sitting function is applied to the tilt mechanism is increasing.

Figure 12. Conversion of various dynamic chairs and its function into office chair

http://jesk.or.kr
though such a function has been appeared independently. Figure 12 introduces the change and integration of the technology for various dynamic chairs. The initial office chair adopted the mechanism to tilt only the backrest backward (back tilt) or tile both backrest and seat pan at the same time (center tilt). But, as various tilt mechanisms were developed later, a new mechanism was adopted to separate the backrest from the seat pan and reflect various dynamic sitting functions. Lately, in order to support more diversified dynamic sitting functions, many efforts have been made to diversify the movement of the tilt mechanism of the office chair. In the past, office chairs could tilt forward or backward only but newly developed chairs can tilt left or right and even in four directions, and office chairs with a shin support pad or chest support pad attached to are now being developed. We expect the trend of introducing various functions to the office chair will continue in the future.

Finally, it is worth paying attention to the process of postural change in a dynamic chair. The process of postural change can be regarded as the control interface. It is not recommended to operate the control device additionally for the postural change. According to sitting behavior study (Grandjean and Hünting, 1983; Ong et al., 1988; Verbeek, 1991), many workers do not control their chairs while sitting on them. Vink et al. (2007) observed 100 office workers and found about 63% of them never used the control function in office chair, and the author pointed out it was caused by the difficulty of operation and lack of understanding. Liesbeth et al., (2009) reported an occupant is supposed to feel more comfortable when the person sitting on a chair can directly control all the functions, and in particular, easy function for backrest sloping helps the person to use the function more frequently. In conclusion, any unnecessary control motion should be minimized to promote the natural dynamic sitting posture of a user.

Peter (2009) developed a chair to meet the occupant’s needs as the angle of the chair varies as the center of gravity of the occupant’s movement, while Okamura, a Japanese office chair manufacturer, launched an office chair adopting the robot mechanism which changes the degree of inclination by predicting the occupant’s posture in cooperation with Oki Co. (Figure 13). Under the current situation in which various functions are applied to one mechanism, it is anticipated the effort on developing office chairs having the free postural change function to cover all of our behaviors will be actively made for the days to come.

**Figure 13.** An example of the chair capable of free posture conversion control to meet the occupant need, Gravity Balans (Peter Opsvik) and Leopard Robot Technology (Oki & Okamura)

In this study, we reviewed the types of dynamic chairs and related technologies. Prior to this, we found out the origin of dynamic chairs from the biomechanical background with references to the previous literature about dynamic sitting. Then, we defined the range of the dynamic chairs in this study, which intends to deal with on the basis of the definition of dynamic sitting. In addition, we identified four dynamic sitting postures in consideration of the occupant behaviors, collected related chair examples, and applied technologies from the biomechanical viewpoint. We think it is manifest the concept presented in this study, e.g. dynamic sitting, occupant’s behavior analysis, related products, and technology trend will be useful for chair development in the future.
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