Hamburg University of Applied Sciences (HAW Hamburg)

Faculty Life Sciences

Master of Health Sciences

Impact of ExerCube-games on the physical and cognitive skills of apprentice nurses in the north-east of Hamburg: a three-armed randomized controlled trial

Master thesis

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Submitted by:

Nina Gurung

[redacted]

Examination supervisor: Prof. Dr. Andre Klussmann

Secondary supervisor: Nizar Müller

Abstract

Background: Physical inactivity is one of the biggest challenges in modern society today. To cope with this challenge, the concept of exergaming (a combination of gaming and fitness) is trending nowadays. This thesis will investigate the effect of one such exergame called the ExerCube on the physical (core stability and cardiorespiratory endurance) and cognitive (concentration and reaction) skills of apprentice nurses in the north-east of Hamburg.

Methods: This is a three-armed randomized controlled trial with 18 participants divided into 3 groups. The intervention group trains with ExerCube, whereas the first control group trains in a fitness studio, and the second control group does not engage in any kind of assigned physical training. Data collection takes place at three time points (t1, t2 and t3) with the help of the FMS test for core stability, the IPN test for cardiorespiratory endurance, and VTS for concentration and reaction. Repeated measures ANOVA has been used for testing how the scores for physical and cognitive skills change over time and differ among the groups.

Results: ANOVA was significant for time points of measurement for core stability ($F[2,26]=3.91$, $p=0.03$, partial $\eta 2=0.2$) and concentration skill ($F[2,26]=3.92$, $p=0.03$, partial $\eta 2=0.2$). A significant interaction was also found between the time points of measurement and age in terms of concentration skill ($F[2,26]=3.47$, $p=0.046$, partial $\eta 2=0.210$). ANOVA was not significant for time points of measurement for cardiorespiratory endurance ($F[1.4,18.4]=0.17$, $p=0.77$) and for reaction skill ($F[1.4,18.4]=1.17$, $p=0.31$). The effect of the group factor was also statistically not significant for any of the variables, as their p-values were >0.05.

Discussion and Conclusion: ExerCube training showed a positive effect on core stability and concentration, while no effect was observed for cardiorespiratory endurance and reaction. However, even though training with ExerCube had a statistically significant effect on core stability and concentration, the group factor did not reach significance in any of the analyses. While interpreting the results, the limitations of this study should also be taken into consideration. Small effect sizes, low participation in the intervention and other limitations lead to the conclusion that in this setting the ExerCube training might not have improved core stability and concentration in the apprentice nurses. Further research could use larger samples and ensure high participation in training sessions to get more robust results.

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List of Abbreviations

ANOVA	Analysis of Variance
COG	Cognitron
COVID	Coronavirus disease
FMS	Functional Movement Screen
HPA	Hypothalamus-pituitary-adrenal
HR	Heart rate
H/V	Hollmann/Venrath
HzHG	Hospital zum Heiligen Geist
IBM	International Business Machine
IPN	Institut für Prävention und Nachsorge
n.d.	No date
rm	Repeated measures
RT	Reaction test
SD	Standard deviation
SPSS	Statistical Packages for Social Sciences
t1	First time point of measurement
t2	Second time point of measurement
t3	Third time point of measurement
VR	Virtual Reality
VTS	Vienna Test System
WHO	World Health Organization

1 Introduction

Physical inactivity emerges as one of the biggest challenges in modern society today. Whereas people in ancient times used to hunt or forage for food and work for any other basic necessities, people in modern society today have direct access to many basic necessities of life without having to move an inch from their couch. This has caused the current generation to remain rather physically inactive. Lack of physical activity is a risk factor for physical and mental health and can contribute to various chronic diseases and conditions (Haskell et al., 2009).

According to recent estimates by the World Health Organization (WHO), it was found that more than one in four adults i.e., 27.5% of the global population do not meet the recommendations for physical activity and thus, are classified as physically inactive. Considering this estimate by the WHO, there is a crucial requirement to take action and increase the priority of promoting physical activity around the globe (Bull et al., 2020). Most people engage in traditional forms of exercises like running, jumping, weightlifting etc. in order to remain fit, however, not everyone is inclined towards traditional forms of fitness. To cope with these challenges and increase physical activity among people, the fitness sectors and the gaming industry have, in the past years, introduced the concept of exergaming i.e., training scenarios based on games (Martin-Niedecken, 2021). In the words of Bogost, exergaming is a term used for a "combination of exercise and video games" (Bogost, 2005). The concept of exergaming was specially developed to motivate those users to fitness, who find it difficult to remain physically active with the traditional way of doing sports or exercises (Barnett et al., 2015).

With the progress in the technological field and increased accessibility of consumer devices, the popularity of exergaming is increasing day by day. Exergames like Nintendo Wii and Sony Move have evolved in the past years from a simple source of entertainment to serious settings for physical training (Martin-Niedecken, Márquez Segura, et al., 2019). These are based on movement and virtual reality (VR) applications. However, there is also a parallel debate that these exergames have their shortcomings. They are mostly focused on the design of the game and may not provide optimal fitness or training to the users' (Martin-Niedecken et al., 2020). Following the concept of exergaming and addressing the shortcomings in the previous exergames, ExerCube was introduced in the year 2018 with holistic and participatory design. The focus of this concept lies on the fitness of the user and adaptivity towards its users (Martin-Niedecken & Mekler, 2018). In recent years, there have been many studies regarding the design, attractivity, and enjoyment of ExerCube sessions (Martin-Niedecken, 2021; Schättin et al., 2022). This thesis is, however, focused on the effects of ExerCube games on physical and cognitive skills and therefore, the other factors like design and attractivity will not be considered in detail.

Research on the effects of various exergaming has been going on for a long time. However, ExerCube being a new game just introduced a few years back, there is only limited research on cognitive skills in comparison to other aspects. This paper serves the purpose of supplementing the ongoing research on the effects of ExerCube gaming on cognitive skills such as concentration and reaction. Along with cognitive skills, the effects of ExerCube gaming on physical skills such as stability and cardiorespiratory endurance will also be explored in this research paper.

Therefore, this thesis aims to examine the effects of the ExerCube game "Sphery Racer" on the physical and cognitive skills of the apprentice nurses in the north-east of Hamburg. The beneficiaries of this study, the nurses, are one of the indispensable workforces who work for the health and safety of sick people. Unfortunately, many people in the nursing profession are prone to career change because of physical and mental challenges they may have to face in their profession. Additional measures of health promotion of nurses through physical activities could contribute to helping them remain physically and mentally healthy. This topic will further be clarified in the following section of the theoretical background. After that, the preparation of the study and data collection will be explained in the methodical section, followed by the description of the results. Finally, the findings of the study are discussed and summarized.

2 Background

2.1 ExerCube

In this chapter, ExerCube will be introduced along with its first game, the Sphery Racer. Then, exercises, functions and settings in ExerCube will be discussed. After that, the influence of exergaming on physical and cognitive aspects of the human body will be explained briefly and possible applications will be described.

2.1.1 Introduction – Sphery Racer

Martin-Niedecken, Rogers, et al. (2019) describe ExerCube as "an immersive and adaptive fitness game setup following a holistic design approach on the levels of body, controller, and game scenario". While training with ExerCube, players are surrounded by three walls that form a cube-like structure. A player inside ExerCube surrounded by its three walls is shown in Figure 1. The player is imitating the movement shown by the avatar on the front wall which acts as a screen.

Figure 1: A player surrounded by three walls inside ExerCube (own image)

The three walls of ExerCube act as projection screens and a tactile interface for dynamic bodily interactions. This enables a mixed-reality game setting inside the cube and creates an immersive experience for the player (Martin-Niedecken, Márquez Segura, et al., 2019). In addition to the immersive experience, the system also provides "dual flow" which adjusts the speed and flow of the game. This means the difficulty level of the game continuously adapts to the fitness- and gaming skills of the player, which creates an optimal training dual flow (Martin-Niedecken et al., 2020). The dual flow concept is "an optimal training/gameplay experience during exergame play that requires a balance between the game-related challenge and player skills, as well as between the intensity of the required movement input and the player's fitness level" (Martin-Niedecken & Mekler, 2018).

Figure 2: Wrist tracker (own image)

Figure 3: Ankle tracker (own image)

ExerCube can be played in different game scenarios. One of the first game scenarios in ExerCube is called "Sphery Racer". The Sphery Racer takes place in a virtual game scenario of a rapid sci-fi-themed underwater race. Before the game starts, the calibration of the player takes place i.e., the player's body is measured to adjust the exercises or movements according to the player's measurements. During the game, the player replicates an avatar, speeds along a racing track through various obstacles, and faces many motor-cognitive challenges in the form of exercises. The movement of the player is tracked by the system through a customized motion tracking system attached to the player's wrists and ankles on each side in the form of arm- and leg bands (Martin-Niedecken, Rogers, et al., 2019). A wrist and ankle tracker tied to the hand and ankle of a player are shown in Figures 2 and 3.

There are also other games in ExerCube that are currently being developed and tested. This study uses the Sphery Racer as an ExerCube game because the other games are still in their test phases and, because Sphery Racer challenges the user physically as well as cognitively, it would be ideal to examine the effects of Sphery Racer on the physical and cognitive skills of the human body.

2.1.2 Exercises in Sphery Racer

The ExerCube game, Sphery Racer, consists of seven different kinds of exercises. The different exercises are meant to train different parts of the body. Touches, punches, and burpees are meant to train the upper body parts, whereas jumps, squats, lunges, and triples are meant to train the lower body.

i. **Touches:** The touches take place at three different levels on either side of the body i.e., the movement can be upward, mid, or low and to the right or left side. For the upward movement, the player must stretch his arms and touch the upward side of the cube extending the leg on the opposite side. For the mid-movement, the player must move his or her body to the side as shown in Figure 4. For the lower movement, the player has to stretch his or her hands on the lower part of the cube. To which side to move, is determined by the avatar displaying the exercise.

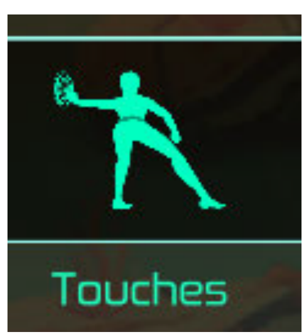

Figure 4: A figure showing mid-level touches exercise (own image)

ii. **Punches:** The punches take place only in the mid-range of the cube i.e., the player has to punch either the left or right side of the cube as displayed by the avatar. It is important to note that this is a rotating movement, and the player must punch the opposite side of the cube i.e., punch on the right wall with the player's left fist and punch on the left wall with the player's right fist. In Figure 5, the player is punching the left wall with the right fist.

Figure 5: A figure showing the punches exercise on the right side (own image)

iii. **Jumps:** Jumps are one of the simple movements in ExerCube. The player must simply jump on his or her standing position as shown in Figure 6. However, it is important to note that both hands must be stretched high in the air while jumping to perform the exercise correctly and then land again in the original standing position with hands down on either side of the body.

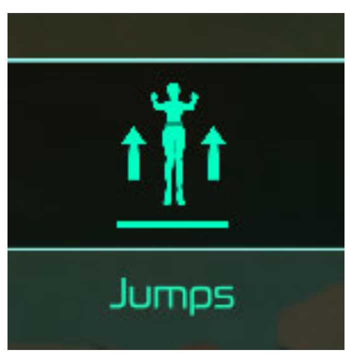

Figure 6: A figure showing jumps exercise (own image)

iv. **Squats:** To perform squats, the player has to squat in his or her position in the centre of the cube. Here it is important to note that the legs are parallel to each other, and both hands are touching the ground while squatting. After performing this exercise, the player must come to his or her original standing position. The position of a squat is shown in Figure 7.

Figure 7: A figure showing squats exercise (own image)

v. **Lunges:** To perform lunges, the player lowers the body keeping the torso straight and moves the left or right leg forward bending both knees. Which side of the leg to move forward is determined by the avatar displaying the exercise. The player must hold this position for a specific time of seconds to perform the exercises correctly and at last, come back to the original standing position. Figure 8 shows a player moving the left foot forward to a lunge position.

Figure 8: A figure showing left foot lunge (own image)

vi. **Tripples:** During this exercise, the player stands in the centre of the cube. The idea is to create a running movement in the same place where the player is standing and move his or her hands and legs as quickly as possible. This movement must be done for a couple of seconds to be performed correctly. The movement of tripples is shown in Figure 9.

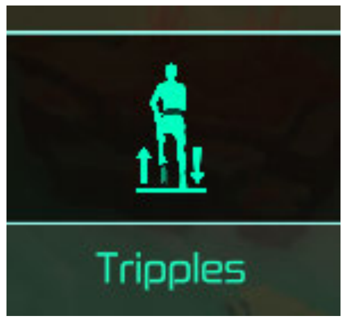

Figure 9: A figure showing the exercise tripples (own image)

vii. **Burpees:** Burpees consist of two movements in total. The player must start this exercise by performing a jump (see ii: jumps). Immediately after the jump, the player must go to a plank position and again return to the original standing position quickly to perform the exercise correctly. The plank position during burpees is shown in Figure 10.

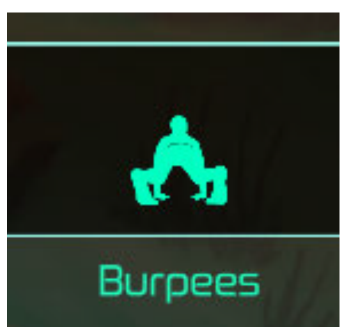

Figure 10: A figure showing the burpee exercise, where it comes to plank position after a jump (own image)

2.1.3 Functions and Settings in ExerCube

There are many functions and settings in ExerCube which will be explained briefly in this section. The first function is that the player can select one of the three options if he or she wants to train the upper body, lower body (leg day), or both (dual flow) as shown in Figure 11. Then the system determines the exercises according to the player's choice. If these exercises are performed correctly at the right time, then the player gets higher scores. If performed before the right time the player gets lower scores, whereas if performed late, the player gets no score at all.

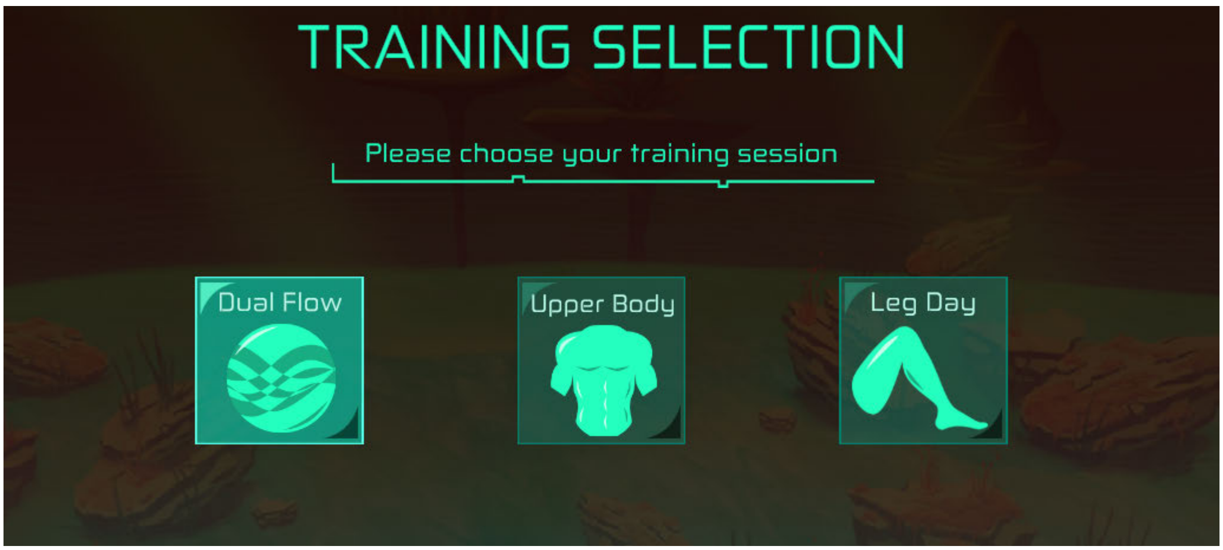

Figure 11: Training selection with the options dual flow, upper body, or leg day (own image)

Another function is the various difficulty level of the game. There are primary, intermediate, and advanced levels for the game. The player decides which level to play. The primary level consists of the first four exercises: touches, punches, jumps and squats. At the intermediate level, the triples and lunges come in addition to the four exercises. And at the advanced level, the burpees are added to all the six exercises. The player must, therefore, perform all the above seven exercises at the advanced level. Figure 12 shows various settings for difficulty selection for the training session in ExerCube. The various settings will be described briefly in the coming paragraphs.

Figure 12: Various settings in ExerCube such as difficulty level, speed, duration, heart rate and tutorial (own image)

Besides the difficulty level, a time setting for the duration of the game is also available in ExerCube. The duration ranges from three to 30 minutes. The player can choose how many minutes he or she would like to train at once or rather at intervals. For example, the player may choose to train for 30 minutes at once with no breaks in between or he or she can also choose to train for 30 minutes but with breaks in between.

There is also a setting for the speed of the game. This means the speed at which the exercises occur can be adjusted before the game. It ranges from zero to 10, zero being the slowest speed and 10 being the highest speed. If the player misses the exercises or cannot perform the exercises in time, the game adapts itself and will be slower adjusting to the player’s pace, whereas if the player performs every exercise correctly at the right time, the game will get faster.

Functions for the heartbeat of the player like maximum heart rate (HR Max) and target heart rate (HR Target) are also present, which will, however, not be used in this study or discussed in this paper. Finally, the person can also choose to follow a tutorial before the beginning of the game where he or she follows instructions about the exercises in ExerCube visually as well as per audio. This is mostly recommended for first-time players. The tutorial can be opted out for experienced players.

Players can see their scores at the end of the game. In addition to scores, they also can see the information on the screen about how many exercises were missed and how many exercises were performed in time. This information is also present in the form of percentages so that the player can work to improve his or her percentage scores. There is a "body score" which depends on how many exercises were performed correctly during the game and there is a "brain score" which depends upon whether the player performed the exercise at the right time during the game. The average of the body and brain score is called "dual score".

2.1.4 Influence on Physical and Cognitive Skills

In this section, the effects of exergaming on physical and cognitive skills will be discussed. In recent years, there have been various studies about the effects of exergaming on physical and motor skill performances. Gao et al. (2019) observed the positive effects of an eight-week-exergaming intervention on the physical activity of preschool children. However, significant effects of exergaming on their motor skills could not be observed (Z. Gao, Zeng, et al., 2019). Similarly, Barnett et al. (2015) found in their study of a six-week exergaming intervention that although exergaming may motivate children towards doing more sports, it has no significant effect on their motor skills. In contrast to these studies, the study of Ye et al. (2018) with nine months of exergaming intervention reported positive effects of exergaming on the musculoskeletal health and body mass index of children in second and third grade. Ketelhut, Röglin, et al. (2022) also conducted a study in a school setting to examine the effect of regular ExerCube sessions and also found positive effects of exergaming. This study showed that integrating regular exergaming sessions in the school setting improved physical fitness in the participating children (Ketelhut, Röglin, et al., 2022). Another study by Ketelhut, Ketelhut, et al. (2022) reported that training with ExerCube was found to result in a significantly higher exercise stimulus compared to moderate endurance training. Martin-Niedecken et al. (2020) concluded that if designed with proper fitness protocol, exergames or fitness games have the potential to increase physical activity and induce health benefits in the participants. Despite some inconsistencies in the results, it can be observed that exergaming somehow influences the physical and motor skills of the player. The variations in the results of these studies could be because of variations in study designs, time period of interventions or the type of exergame intervention used in the study.

Along with physical and motor skills, there have also been many studies on the effects of exergaming on cognitive skills. Wang et al. (2021) found in a study with 12 weeks of exergaming intervention that exergaming training sessions helped improve executive functions in older adults. Similarly, Zhao et al. (2022) also demonstrated in their study with healthy older adults that 12 weeks of exergaming sessions improved working memory and executive functions. A systematic review by Serrano et al. (2021) with 13 studies indicated a positive effect of exergaming sessions on the cognitive functions of young people ages six to 18 years old. In this systematic review, cognitive functions that were investigated in the studies were executive functions such as attention, reaction skills, working memory, intellectual processing, and motor planning (Serrano et al., 2021). Furthermore, in a study by Anders et al. (2018) brain activity of 24 young adults during exergaming sessions was recorded. This study reported that even simple exergames with little cognitive demands required a lot of cognitive processing in the participants' minds during exergaming sessions (Anders et al., 2018). These results are an indication of the positive effects of exergaming sessions on the cognitive skills of the players if practiced in the long term.

2.1.5 Possible Applications of ExerCube

The ExerCube can be used by people across various age ranges. It can vary from children above 6 to 8 years old to older adults more than 65 years old, who are cognitively in a place to understand and grasp the concept of exergaming. The ExerCube can also be played in a sitting position in a chair or stool as shown in Figure 13. Thus, it can also be used by people who use wheelchairs or are otherwise unable to stand for a long period of time. People in wheelchairs can also use their wheelchairs instead of the chair.

Figure 13: Elderly playing ExerCube in a sitting position (own image)

Ringgenberg et al. (2022) a qualitative study with older adults who were more than 65 years of age and with health professionals as focus groups. Here, people who use wheelchairs were also included as participants. This study focused on finding solutions for ExerCube to be more adaptive, safe, and motivating to older people. It was found that including a safety system, different performance levels, high scoreboards, realistic games, and feedback on the performance will help develop exergaming to expand its application (Ringgenberg et al., 2022). However, for the usage of ExerCube by elderly people, it should also be noted that they should be trained thoroughly by health professionals beforehand. Older people with terminal illness or intensive pain during movement are recommended to consult a health professional before using ExerCube or not use it at all. It is also important to note that a trainer or health professional should be present for vulnerable groups such as children and older adults to ensure safety.

2.2 Physical Activity

In the following paragraphs, the definition and importance of physical activity will be explained. After that, the prevalence of physical activity in apprentice nurses will be discussed.

2.2.1 Definition

World Health Organization (WHO) defines physical activity “as any bodily movement produced by skeletal muscles that requires energy expenditure. Physical activity refers to all movement including during leisure time, for transport to get to and from places, or as part of a person’s work” (WHO, n.d.). Considering the various benefits of physical activity, WHO has guidelines and recommendations for remaining physically active for different age groups of people. Because the study for this paper is focused on adults aged 18 to 64 years as beneficiaries, only guidelines and recommendations for people in the age group of 18 to 64 years are mentioned here.

Guidelines and recommendations by the WHO suggest that all adults should practice physical activity regularly. Strong recommendations by the WHO for adults aged 18 to 64 years are as follows:

- “Adults should do at least 150–300 min of moderate-intensity aerobic physical activity, or at least 75–150 min of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate-intensity and vigorous-intensity activity throughout the week for substantial health benefits” (Bull et al., 2020);
- “Adults should also do muscle-strengthening activities at moderate or greater intensity that involve all major muscle groups on two or more days a week, as these provide additional health benefits” (Bull et al., 2020).

2.2.2 Importance of Physical Activity

In the case of general mortality, the positive effects of regular physical activity are well documented in the literature. For example, Leitzmann et al. (2007) demonstrated that the risk of mortality decreased by 27% in a population of 252,925 women and men, provided that the subjects followed the guidelines and general recommendations for moderate physical activity (at least 30 minutes of moderate-intensity physical activity on most days of a week). In subjects, who implemented the recommendations for very strenuous physical activity (at least 20 minutes of very strenuous physical activity on at least three days per week), the risk of mortality decreased by as much as 32%. Using an objective measurement method in their study, Manini et al. (2006) were able to show that the mortality risk was significantly reduced for individuals, whose physical activity led to an additional energy consumption of more than 287 kcal per day.

Numerous studies confirm the positive influence of physical activity from a rehabilitative or preventive point of view. Remaining physically active can decrease the risk of various health complications. These complications include cardiovascular diseases, liver diseases, type 2 diabetes, hypertension, adiposity, and site-specific cancers (Bull et al., 2020). In a prospective study, Blair et al. (1989) demonstrated that a high level of cardiorespiratory fitness reduces mortality. In this study, the fittest men and women had a 43% and 53% lower risk of overall mortality and a 47% and 70% lower risk of cardiorespiratory mortality compared with the group of men and women who were least fit.

The fact, that regular physical activity helps individuals cope with anxiety and depressive symptoms has been known for a long time. It helps in the relief of nonpsychiatric chronic diseases like fibromyalgia (a condition in which the person experiences severe pain all over the body) and diverse conditions such as menopause and nicotine abstinence. Physical activities tend to decrease stress tendencies in individuals, while also improving mood, self-esteem, cognition, focus, decision-making, etc. People who engage in regular activity are found to be in a better state of mind in comparison to those who don’t (Mahindru et al., 2023; Peluso & Andrade, 2005).

The impact of physical activity on the hypothalamus-pituitary-adrenal (HPA) axis is illustrated in Figure 14. HPA axis is “an interactive neuroendocrine unit comprising of the hypothalamus, the pituitary gland, and the adrenal glands. The hypothalamus is located in the brain and the pituitary at the base of it, whereas the adrenals are on top of the kidneys” (Heaney, 2013). The HPA axis is responsible for the secretion of cortisol. It maintains the equilibrium in the internal environment of the human body and the body’s reaction towards stress. As seen in Figure 14, physical activity improves the functioning of the HPA axis, which leads to the reduction of cortisol levels. The reduction of cortisol levels further helps in restoring the balance of leptin and ghrelin (Mahindru et al., 2023). Leptin and ghrelin are the hormones responsible for bodily functions such as food intake and metabolism, body weight and sleeping habits, which play an essential role in maintaining the fitness of the body (Klok et al., 2007; Taheri et al., 2004).

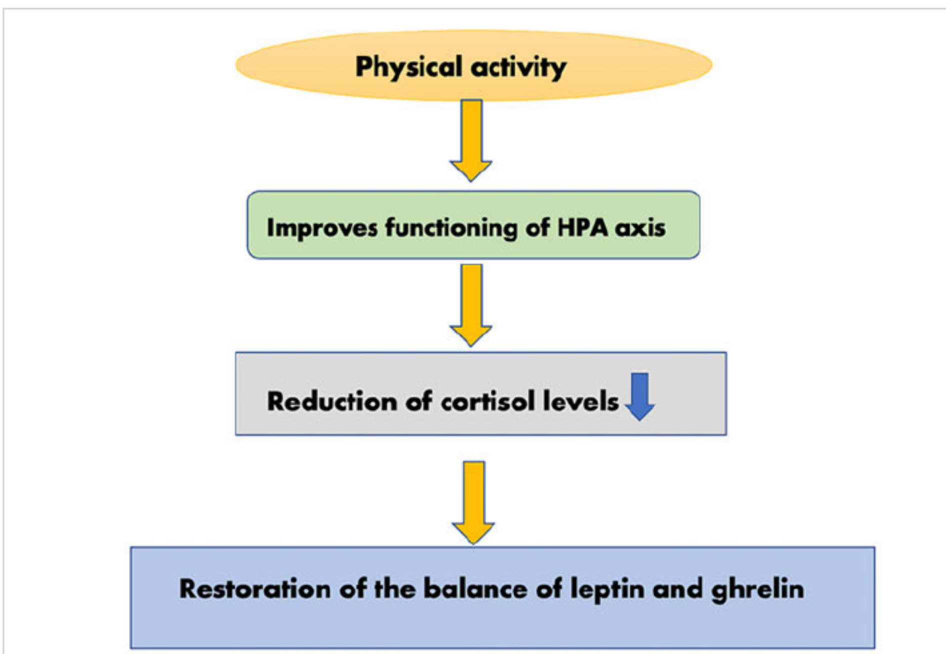

Figure 14: Impact of physical activity on the HPA-Axis (Mahindru et al., 2023)

2.2.3 Physical Activity in the Nursing Profession

Many studies have shown that physical inactivity is somewhat prevalent in the nursing occupation. In the cross-sectional study of Wirth et al. (2016) with a sample size of 354 apprentice nurses, it was found that only 25 % of them were active in sports. The amount of time engaged was less than two hours per week. It was observed that physical inactivity is prevalent in the nursing profession. Another study by Lehmann et al. (2014) found a lower prevalence of physical inactivity in their study with 259 apprentice nurses. Here, the percentage of apprentice nurses who exercised less than once a week was 28.5 %.

There are various reasons for the prevalence of physical inactivity among apprentice nurses or in general, in the nursing profession. The apprentice system in Germany is highly practically oriented. The apprentices spend a huge amount of time in the workplace besides school education. The field of nursing is one of the occupations, where the apprentices are exposed to performance stress at school and their workplace. The occupation of nursing is known to be related to a high amount of physical and emotional stress. Particularly most of the apprentices are also going through the stage of entering adulthood and are vulnerable to an unhealthy lifestyle, which mostly includes a lack of physical activity (Wirth et al., 2016). Besides this, working in alternating night shifts has also been shown to reduce physical activity in leisure time among nurses. Compared to other occupational groups in the health profession, nurses show the lowest physical activity (Mojtahedzadeh et al., 2021).

Based on this backdrop, it seems crucial to promote the health and physical activities of the apprentices in the nursing sector, as they are the ‘professionals of tomorrow’ (Popp et al., 2020). Promoting physical activity in professions such as nursing can be an effective approach towards promoting health and workability (Carl et al., 2020).

2.3 Physical Skills

Physical skill is the ability of an individual to use body and strength to resolve physical tasks (Florida et al., 2012). Physical skills within this thesis are referred to core **stability** and cardiorespiratory **endurance** of the body.

2.3.1 Core Stability

Rudd et al. defined stability skills as "the ability to sense a shift in the relationship of the body parts that alter one's balance, as well as the ability to adjust rapidly and accurately to these changes with the appropriate compensating movements" (Rudd et al., 2015). Core stability helps to maintain an equilibrium position. It can be a contributing factor in athletic performance and is also helpful in injury prevention of the body. Furthermore, maintaining a vertical position of the body is essential in performing daily activities, movements, and sports. In case the stability of the body's trunk is not strong, it can lead to health problems like lower back pain (Borghuis et al., 2008).

2.3.2 Cardiorespiratory Endurance

Cardiorespiratory endurance refers to "the ability of the heart and lungs to deliver oxygen to working muscles during continuous physical activity, which is an important indicator of physical health" (Cheng et al., 2019). People who have high cardiorespiratory endurance can exercise for a longer time. They have lower fatigue, take little time to recuperate and do not get tired easily in comparison to people with low cardiorespiratory endurance. Good heart and lung health is an essential and contributing factor in maintaining physical health and prevents various kinds of cardiorespiratory diseases (Cheng et al., 2019).

2.4 Cognitive Skills

The capability of an individual to resolve tasks intellectually can be referred to as cognitive skills. Here, the individual's ability to solve the task successfully depends on his or her cerebral-based knowledge rather than physical prowess (VanLehn, 1996). Cognitive skills within this thesis refer to the **concentration** and **reaction skills** of the human mind.

2.4.1 Concentration

Sörqvist et al. (2016) define concentration as "the ability to selectively attend to a target stimulus and ignore other sources of information (selective attention), and it also refers to the dynamic mechanism of task engagement". Concentration can range from low to high depending on factors such as cognitive challenge, motivation, time pressure, and individual trait ability for attentional engagement. The concentration of the mind is an essential component in daily life as concentration helps an individual focus on what's important whilst ignoring information that is irrelevant (Sörqvist & Marsh, 2015).

2.4.2 Reaction

There are many definitions of reaction available in the Cambridge Dictionary. Within this paper, reaction refers to "someone's ability to act quickly when something happens" (Cambridge, 2023). Furthermore, Chu et al. (2013) describe the reaction time as "the delay between a sensory stimulus and a behaviour response". According to the Vienna Test System (VTS), reaction or reactive behaviour is reactive stress tolerance. N. Ong (2017) defined reactive stress tolerance as the ability of an individual to function and react quickly and correctly under stressful conditions. Reactive stress tolerance depends upon factors such as age, gender, sport, and competitive level (Kiss & Balogh, 2019).

2.5 Research Objectives and Research Question

The objectives of the research study are divided into general objective and specific objectives that are listed below:

General objective:

- To investigate the impact of ExerCube games on the physical (core stability and cardiorespiratory endurance) and cognitive (reaction and concentration) skills of apprentice nurses by motivating them towards fitness with the help of ExerCube-training

Specific objectives:

- To include training with ExerCube as a part of occupational health management
- To develop better practices for fitness and exercise

Does training with ExerCube games improve the physical (core stability and cardiorespiratory endurance) and cognitive (reaction and concentration) skills of apprentice nurses?

3 Method

3.1 ExerCube Project

The ExerCube project belongs to Hospital zum Heiligen Geist (HzHG). It is the oldest foundation in Hamburg established in the year 1227. In HzHG, elderly seniors are cared for and looked after in various forms of living and services. This organization aims to provide elderly seniors with various quality services and facilities that ensure quality of life (HzHG, 2022).

To add a variation to the sports activities that are offered as services in HzHG, the ExerCube project was created, however not just limited to the seniors living there. With the help of sponsors, two ExerCubes were brought in at HzHG. The ExerCube is also available as a sports activity to the employees, the apprentice trainees and external people who do not belong to HzHG.

This present study is sponsored by *Mobil Krankenkasse* and is a sub-project to the main ExerCube Project. The idea was to develop a study that could scientifically prove the benefits of training with ExerCube games. This study is longitudinal and uses a quantitative approach. It includes the evaluation of the core stability, cardiorespiratory endurance, concentration, and reaction skills at three different points of time.

The application for ethical approval was applied at the ethics commission of HAW Hamburg (*Hochschule für Angewandte Wissenschaften*) in May of 2021 using the application form available on the website of HAW Hamburg. This application was then adjusted and improvised according to the feedback of the ethics commission. Ethical approval was then obtained in March of 2022.

3.2 Study Design

This study is designed as a **three-armed randomized control trial** with an intervention of six months. The sample size was calculated using G*Power of Version 3.1.2 from Heinrich Heine University of Dusseldorf, Germany. An effect size of 0.8 with an alpha power of 0.05 was presumed during the sample size calculation, which required a total of 18 participants for the study to have sufficient power. As participants, nursing trainees (N=18) from Alstertal Nursing School in the north-east of Hamburg were recruited. They were randomly assigned into three groups: an intervention group with ExerCube, a fitness studio group and a control group with no assigned physical training. The latter two are the waitlist control groups.

Randomization of the participants was done with the help of cheat sheets. 18 cheat sheets were prepared for the 18 participants with group number one for ExerCube, group two for Fitness-studio and group three for control. The participants were asked to draw from the cluster of cheat sheets and the group was assigned to the participant depending on which group was written in the cheat sheet. In this way, the randomization of the participants took place.

While study participants in the intervention group have immediate access to ExerCube and will be able to train with it, participants in the two-waitlist control group will have to wait six months and one year respectively and will then have access to ExerCube. It is to be noted that this paper only covers the first six months of the study intervention, where the first ExerCube group completes its training with ExerCube. The training sessions are supposed to take place two times a week and the participation in the training sessions will be registered each time. How regularly the participants take part in the training will be a determinant of motivation to train with ExerCube. In the meantime, the participants in the fitness-studio group are expected to engage themselves in some form of sport or exercise, also two times per week at a similar level as the ExerCube group. The control group is not assigned any kind of physical training within this study. The duration of time for the study is six months (for the first intervention group) to approximately one and a half years (for the last wait-list control group until their intervention is completed). Participation in this study is voluntary. The requirement is that the participants are healthy, do not show any type of bodily dysfunction or injury and are able to participate in daily activities. The study has a prospective design with three time points of measurement: t1 (baseline measurement), t2 (after 3 months), and t3 (after 6 months, at the end of the intervention). The physical (stability, endurance) and cognitive (concentration, reaction) skills of all the participants will be measured at the three time points of measurement. The results will then be analyzed using Statistical Package for the Social Sciences (IBM SPSS). Repeated measures Analysis of Variance (rm ANOVA) will be used to compare the means between the three groups and pre- and post-intervention results. Figure 15 shows the schematic representation of repeated measure ANOVA for the three groups in the three time points of measurement. The between-subject factors denote the comparison between the three groups whereas the within-subject factors denote the comparison between pre- and post-intervention results.

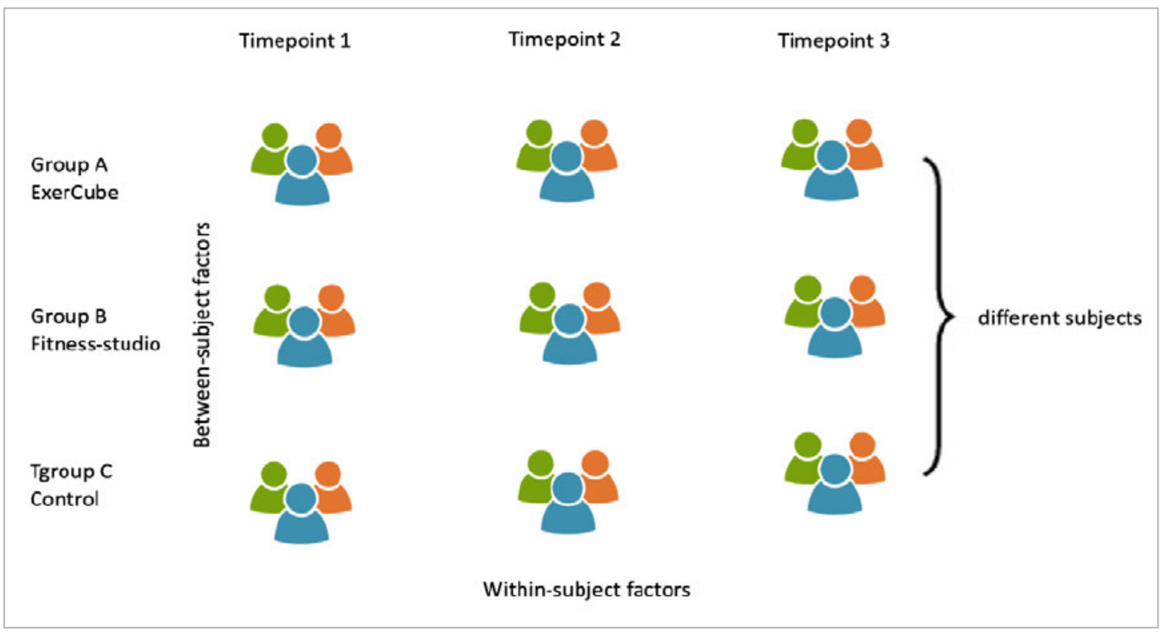

Figure 15: Schematic representation of rm ANOVA for the three groups in the three time points of measurement (created by the author)

3.3 Training Concept and Procedure

The training concept was developed based on a previous study by Martin-Niedecken et al., where 26 to 28 minutes of ExerCube session is considered to be a complete workout (Martin-Niedecken et al., 2020). In our study, it was found through interviews that most of the participants were low to moderately physically active. Due to this reason, the training time of ExerCube was reduced to as little as 15 minutes and it could go as high as 30-40 minutes depending on the capacity of the participant. Participants were provided the opportunity to train two times per week. The duration, speed and difficulty levels of the game described in Capital Two of this thesis were self-regulated by the participants. Breaks in-between games were also self-regulated by participants which were about two to five minutes. An instructor was always present during ExerCube sessions, to guide the participants during the training and provide support, in case support was needed.

To start with the training session, the participant has to enter his or her name or nickname if they like. The duration, speed, and difficulty levels are also entered as desired by the participants. After entering this information into the system, wrist and ankle trackers are tied to the legs and hands of the participants with the help of fitness bands. The player then enters the ExerCube. These tracking systems are connected to the ExerCube with the help of wireless technology called Bluetooth. At first, calibration of the player takes place i.e., the tracking system measures the player's body as shown in Figure 16. This helps with adjusting the exercises according to the player's body measurements. After calibration, a short tutorial about the exercises takes place as shown in Figure 17, where the player gets the movement instructions per visual as well as per audio. The player must move according to the instructions displayed on the front wall of the cube which acts as a display screen.

Figure 16: Calibration in ExerCube (own image)

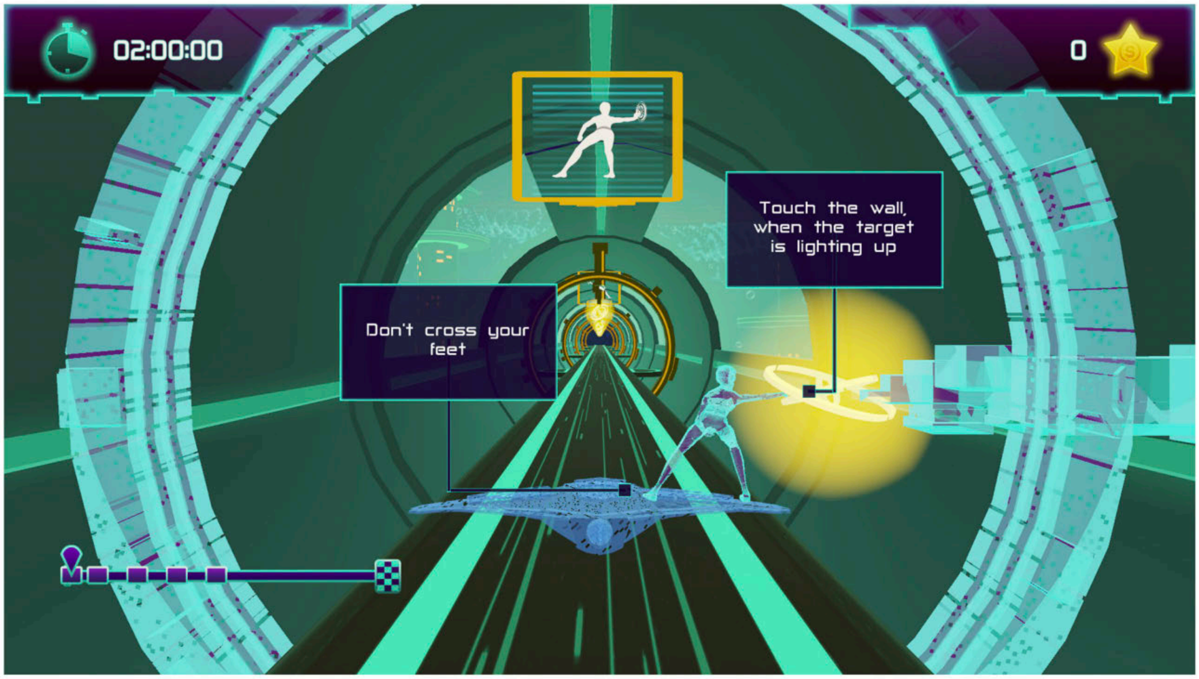

Figure 17: Tutorial in ExerCube before the start of the game (Martin-Niedecken et al., 2020)

After successfully completing the tutorial, the game starts with low intensity at first. The player must perform the exercises shown on the screen, which he or she learned during the tutorial. The game gradually increases its speed and intensity according to the capacity of the player. This is determined with the help of the motion tracking system. If the player is unable to perform the exercise correctly or does not manage to do it at the correct time, the progress of the game concerning speed will not take place. But in case, the exercise is performed correctly and at the right time, the speed of the game will increase gradually until the desired speed or flow of the game is reached. The game is timed according to the setting entered by the player. However, there is no obligation to complete the training session. If the player cannot train further, he or she can cancel or postpone the training session by simply coming out of the ExerCube.

3.4 Preliminary Study

A preliminary study was carried out before starting the actual study. Preliminary studies are mostly done "to refine the intervention and evaluate its acceptability, feasibility, cost, and uptake". They can also be helpful to estimate the acceptance of the trial in the community. There may be some preliminary studies that are large and on a greater scale, but most of the preliminary studies are normally conducted on a small scale and are very quick and effective to test the intervention (Smith et al., 2015).

The preliminary study within the ExerCube Project helped with refining the intervention as well as in designing the methods for the main study. The preliminary study consisted of a smaller number of participants than the main study with a shorter timeframe of about two to three months. The recruitment mostly took place through advertising the project during the school hours of the apprentice nurses. This was done by contacting the teaching staff and asking for their permission to introduce the project to the apprentice nurses. There were about nine apprentice nurses from the Alstertal Nursing School who willingly agreed to participate in the preliminary study. Two participants dropped out during the preliminary study. After experiences learned from the preliminary study, the methods of this study were corrected and adjusted accordingly.

3.5 Study Timeline

After carrying out the preliminary study, the study timeline was created. A short version of the timeline for the baseline measurement and follow-ups of the study is represented in Figure 18. In September and October of 2022, the recruitment of apprentice nurses at Alstertal Nursing School took place. After the recruitment, baseline measurements of the participants were taken in October and November of 2022 for the data collection. Here all the participants had to go through all four tests: Functional Movement Screen Test, cardiorespiratory endurance test and Vienna test system (Cognitron and Reaction Test). These tests will be described thoroughly in the coming sections. The first follow-up took place in February of 2023 i.e., all the tests were repeated during this time. The second or the last follow-up took place in May of

2023. Here, the tests were repeated for the last time with the participants for post-intervention data collection.

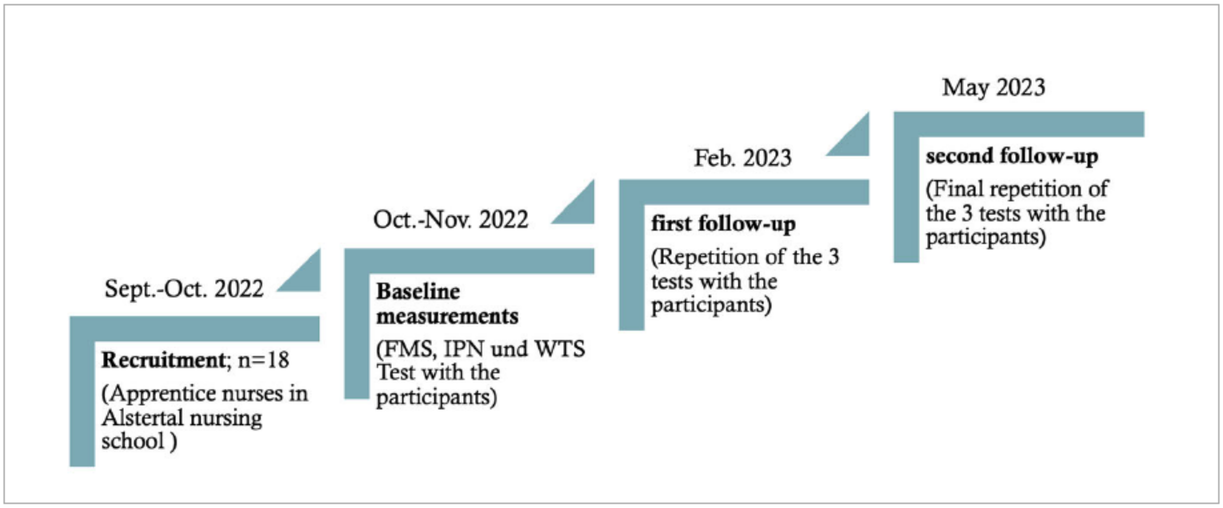

Figure 18: Timeline of the study

3.6 Recruitment

The beneficiaries of this study were the apprentice nurses of the Alstertal Nursing School, which is located on the premises of HzHG. For the recruitment, 92 apprentice nurses were contacted during their school hours with the permission of the director of the nursing school and the teaching staff. The apprentice nurses were informed about the project in the form of a PowerPoint presentation and additionally, handouts about the project were given (s. Appendix I). These materials contain information about the aim of the study, the method, and the study procedure. The apprentice nurses were given contact information in case they have an interest in participating in this study. The contact took place through email address, telephone number and social media platform WhatsApp. The participants were further informed by word-of-mouth that participation in this study is anonymous, and they can cancel their participation at any point in time. This information was also given out in written form as a declaration of consent and usage instructions for ExerCube (s. Appendix II and III) to the participants who were interested in taking part in this study. These documents were to be read carefully and signed by the participants; in case they agree to their participation.

3.7 Data Collection

3.7.1 Instruments for Assessment of Physical Skills

Assessment of physical skills includes the observation of core stability performance with the help of the Functional Movement Screen test and endurance performance with the help of the cardiorespiratory-ergometer test.

3.7.1.1 Functional Movement Screen (FMS) for Core Stability

Core stability performance would be assessed with the help of the Functional Movement Screen test. Functional Movement Screen test (FMS) is "a movement-competency-based test battery aimed to provide a clinically interpretable measure of movement quality" (Marques et al., 2017). This test has been used widely as a screening tool in the field of sports and sports medicine for rehabilitation, to reduce the risk of injury, enhance performances and develop training programs for athletes (Marques et al., 2017).

This test includes seven exercises that are to be performed by the participants. As illustrated in Figure 19 the exercises are as follows:

1. Deep squat
2. Hurdle step
3. In-line lunge
4. Shoulder mobility
5. Rotary stability
6. Active straight leg raise, and
7. Trunk stability push-up.

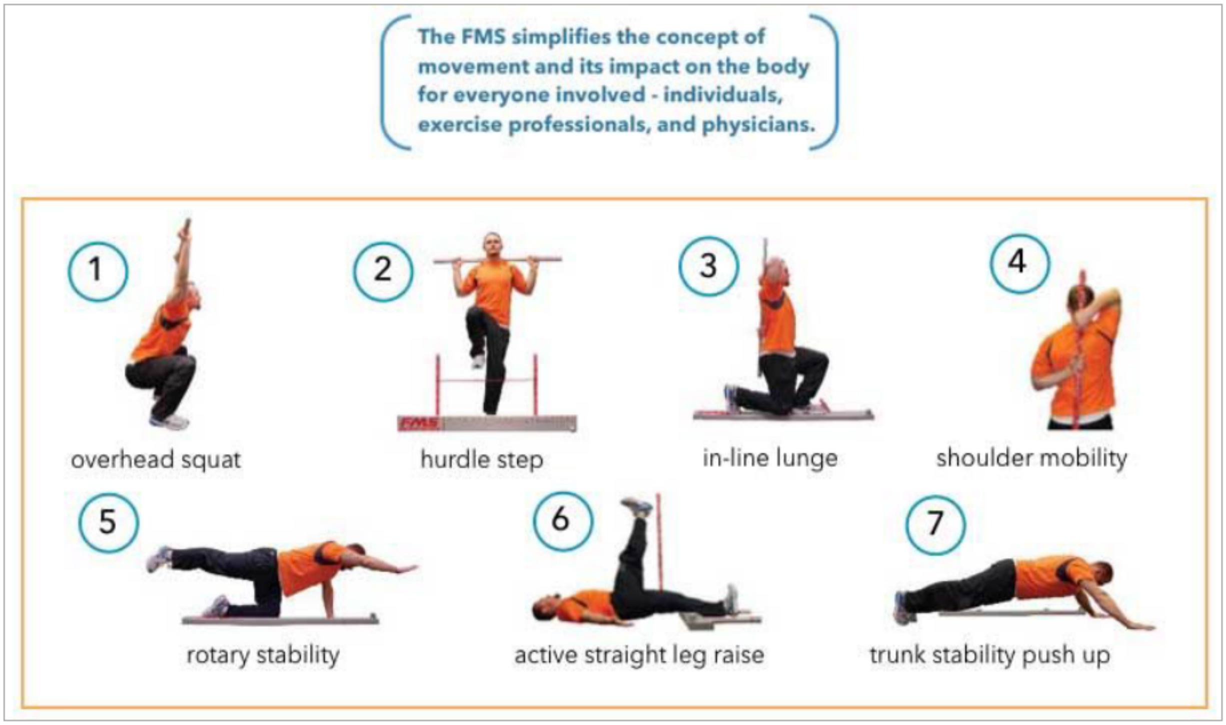

Figure 19: Seven exercises in the Functional Movement Screen test (Gali et al., 2021)

These exercises are performed in the exact order as shown in the figure. Each exercise is scored independently. The score ranges from zero to three (0, 1, 2 or 3 points), where zero is the lowest score and indicates low mobility and pain during the exercise and three is the highest score and indicates high mobility (Gulgin & Hoogenboom, 2014). Participants perform two trials for each of the seven exercises on either side of the body and the lesser score would be considered for the analysis. Participants can score as high as 21 points. Participants with an FMS composite score of less than 15 points are usually classified in the group of people with high risk of injury (Marques et al., 2017).

3.7.1.2 Cardiorespiratory Test for Endurance

An ergometer device is used to assess the cardiorespiratory endurance capacities of the participants. This is carried out with the help of the *Institut für Prävention und Nachsorge*, Cologne (IPN) test. This test is suitable and is chosen because when performing this test, the participants are not pushed to their maximum capacity and are not fatigued. The ergometer device used in this study was available in the fitness studio of HzHG which is illustrated in Figure 20. In this paper, the cardiorespiratory endurance test and the IPN test will be used synonymously.

Figure 20: Ergometer device for IPN Test (own image)

During this test, the age, weight, gender, and training status of the person are entered into the ergometer. The target heart rate for the participant is then specified by the ergometer accordingly. The loading scheme of the ergometer is adjusted according to the World Health Organization (WHO) or the Hollman/Venrath (HV) scheme. In the WHO loading scheme, the initial resistance is 25 watts with an increase of 25 watts every two minutes and, in the Hollmann/Venrath scheme the initial resistance is 30 watts with a 40-watt increase every three minutes. The WHO scheme is more accurate for all women and untrained, older men, whereas the HV scheme is accurate and suitable for trained and overweight men (*IPN-Test*, n.d.).

The test result (relative watt value) is calculated in watts per kilogram of the body mass of the participant using the formula:

Relative watt value: [W1 + (W2 – W1) X (P – P1) / (P2 – P 1)] / KG*

where W1 is penultimate value,

W2 is the last watt value,

P is the resting heart pulse,

P1 is the heart pulse during W1,

P2 is the heart pulse during W2, and

KG is the weight of the participant.

The calculated result is then compared to a relative normal value table. This table is different for women (table 1) and men (table 2). As seen in table 1 and 2, the higher the factor i.e., the relative watt value, the better the endurance performance. The evaluation ranges from "- -" to "+ +", where "- -" means low endurance performance and "+ +" means higher endurance performance. There is also a normal endurance value in between "- -" and "+ +" which is denoted by "ø". The IPN test is commonly used in determining cardiorespiratory fitness and planning training loads for sportsperson (*IPN-Test*, n.d.).

For women:

Faktor/Alter	< 30	30-34	35-39	40-44	45-49	50-54	55-59	ab 60	Bewertung
0,50	**1,15**	**1,09**	**1,04**	**0,98**	**0,92**	**0,86**	**0,81**	**0,75**	- -
0,51	1,2	1,14	1,08	1,02	0,96	0,90	0,84	0,78	- -
0,52	1,25	1,19	1,13	1,06	1,00	0,94	0,88	0,81	- -
0,53	1,3	1,24	1,17	1,11	1,04	0,98	0,91	0,85	- -
0,54	1,35	1,28	1,22	1,15	1,08	1,01	0,95	0,88	- -
0,55	**1,40**	**1,33**	**1,26**	**1,19**	**1,12**	**1,05**	**0,98**	**0,91**	**-**
0,56	1,45	1,38	1,31	1,23	1,16	1,09	1,02	0,94	-
0,57	1,50	1,43	1,35	1,28	1,20	1,13	1,05	0,98	-
0,58	1,55	1,47	1,40	1,32	1,24	1,16	1,09	1,01	-
0,59	1,60	1,52	1,44	1,36	1,28	1,20	1,12	1,04	-
0,60	**1,70**	**1,62**	**1,53**	**1,45**	**1,36**	**1,28**	**1,19**	**1,11**	**Ø**
0,61	1,80	1,71	1,62	1,53	1,44	1,35	1,26	1,17	Ø
0,62	2,00	1,90	1,80	1,70	1,60	1,50	1,40	1,30	Ø
0,63	2,10	2,00	1,89	1,79	1,68	1,58	1,47	1,37	+
0,64	2,30	2,19	2,07	1,96	1,84	1,73	1,61	1,50	+
0,65	**2,40**	**2,28**	**2,16**	**2,04**	**1,92**	**1,80**	**1,68**	**1,56**	**+**
0,66	2,60	2,47	2,34	2,21	2,08	1,95	1,82	1,69	+ +
0,67	2,80	2,66	2,52	2,38	2,24	2,10	1,96	1,82	+ +
0,68	3,00	2,85	2,70	2,55	2,40	2,25	2,10	1,95	+ +
0,69	3,20	3,04	2,88	2,72	2,56	2,40	2,24	2,08	+ +
0,70	**3,40**	**3,23**	**3,06**	**2,89**	**2,72**	**2,55**	**2,38**	**2,21**	+ +

Table 1: Relative watt norm value (per kilogram) for women (IPN-Test, n.d.).

For men:

Faktor/Alter	< 30	30-34	35-39	40-44	45-49	50-54	55-59	ab 60	Bewertung
0,50	1,45	1,38	1,31	1,23	1,16	1,09	1,02	0,94	- -
0,51	1,50	1,43	1,35	1,28	1,20	1,13	1,05	0,98	- -
0,52	1,55	1,47	1,40	1,32	1,24	1,16	1,09	1,01	- -
0,53	1,60	1,52	1,44	1,36	1,28	1,20	1,12	1,04	- -
0,54	1,65	1,57	1,49	1,40	1,32	1,24	1,16	1,07	- -
0,55	**1,70**	**1,62**	**1,53**	**1,45**	**1,36**	**1,28**	**1,19**	**1,11**	**-**
0,56	1,75	1,66	1,58	1,49	1,40	1,31	1,23	1,14	-
0,57	1,80	1,71	1,62	1,53	1,44	1,35	1,26	1,17	-
0,58	1,85	1,76	1,67	1,57	1,48	1,39	1,30	1,20	-
0,59	1,90	1,81	1,71	1,62	1,52	1,43	1,33	1,24	-
0,60	**2,00**	**1,90**	**1,80**	**1,70**	**1,60**	**1,50**	**1,40**	**1,30**	**Ø**
0,61	2,20	2,09	1,98	1,87	1,76	1,65	1,54	1,43	Ø
0,62	2,40	2,28	2,16	2,04	1,92	1,80	1,68	1,56	Ø
0,63	2,60	2,47	2,34	2,21	2,08	1,95	1,82	1,69	+
0,64	2,80	2,66	2,52	2,38	2,24	2,10	1,96	1,82	+
0,65	**3,00**	**2,85**	**2,70**	**2,55**	**2,40**	**2,25**	**2,10**	**1,95**	**+**
0,66	3,20	3,04	2,88	2,72	2,56	2,40	2,24	2,08	+ +
0,67	3,40	3,23	3,06	2,89	2,72	2,55	2,38	2,21	+ +
0,68	3,60	3,42	3,24	3,06	2,88	2,70	2,52	2,34	+ +
0,69	3,80	3,61	3,42	3,23	3,04	2,85	2,66	2,47	+ +
0,70	**4,00**	**3,80**	**3,60**	**3,40**	**3,20**	**3,00**	**2,80**	**2,60**	+ +

Table 2: Relative watt norm value (per kilogram) for men (IPN-Test, n.d.)

3.7.2 Instruments for Assessment of Cognitive Skills

The cognitive abilities of the participants will be tested using the Vienna Test System (VTS). The Vienna test system is a computerized assessment tool that combines a wide variety of psychological tests into one user-friendly platform. It was developed by Schuhfried GmbH. This test system is mostly used in various aspects of sports psychology and provides a valid and reliable testing procedure. Vienna Test System is "suitable for assessing both ability and personality in athletes, and includes tests of many different constructs such as sustained attention, reaction time, peripheral perception, stress reactivity, and time movement anticipation" (N. C. H. Ong, 2015). Figure 21 shows a computer with VTS software and a keyboard with colorful buttons to be used with the VTS software during the tests.

Figure 21: Vienna Test System (Macedo et al., 2019)

Out of the many tests and test sets available in the online marketplace of Schuhfried, suitable tests to measure concentration and reaction ability were searched. The test suitable for measuring concentration skill was found to be the Cognitron test and for measuring the reaction skill, the Reaction test was chosen. Both tests will be described briefly in the coming paragraphs.

3.7.2.1 Cognitron from Vienna Test System for Concentration

For the assessment of the concentration performance, the Cognitron (COG) test is used. The ability to concentrate is one of the most needed cognitive abilities to perform daily activities. Because of its practical use, the Cognitron test is used in various fields such as clinical neuropsychology, safety assessment, investigations in traffic psychology and sport psychology. There are various test forms in the cognitive test with flexible working time and fixed working time. During these tests, the participants should compare one geometric figure to the other geometric figures. In the flexible working time, the participants should press different keys to specify if the geometrical figures are identical. In the fixed working time, the participants only have a limited time to identify the geometrical figures. Depending on the test form, the participants may need about five to 20 Minutes to complete the test (*COG*, n.d.).

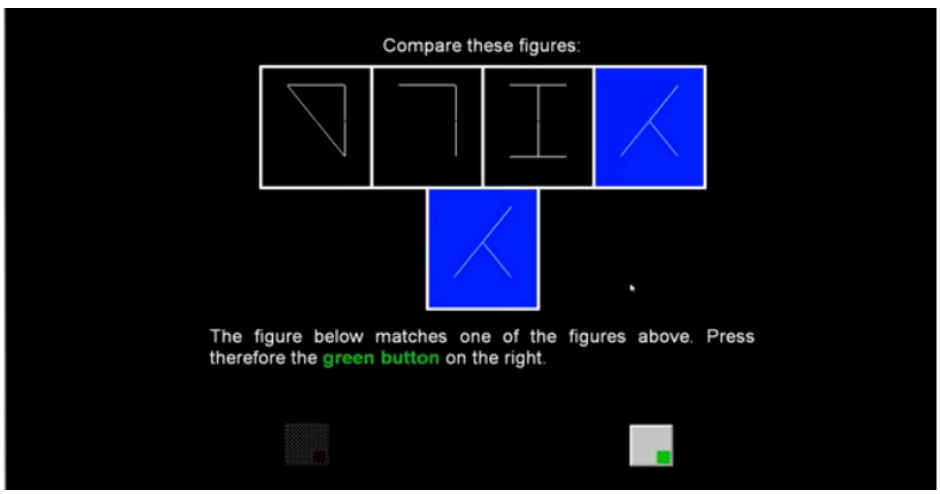

Figure 22: Cognitron test (COG, n.d.)

Cognitron consists of various test forms for various purposes within the field of concentration. For the assessment of the concentration performance of the participants within this study, the test form S11 is used. S11 measures "the speed of the participants during concentrated working" (COG, n.d.). A representation of the Cognitron test is seen in Figure 22. There are figures on the computer screen that must be compared. Depending upon if the figure matches one of the figures above, the participant must press the green or red button on the keyboard. For this test, the participants only have a limited time of about three to five seconds till the next set of figures appears.

3.7.2.2 Reaction test from Vienna Test System for Reaction

The Reaction test uses stimulus constellations to evaluate the reaction performance of the participants. There are simple choice and multiple-choice reactions to measure the time of reaction. Here, the stimulus modalities light/sound and the features with choices of red/yellow/white are available, to create different stimulus constellations for measuring the reaction time of the participants. The stimulus constellation can vary from individual to synchronous or chronological combinations. Depending on the form of the test, the time for the test could take about five to 10 minutes. Reaction tests are mainly used in safety assessments, traffic psychology, sports psychology, and pharmaco-psychology fields (*RT*, n.d.).

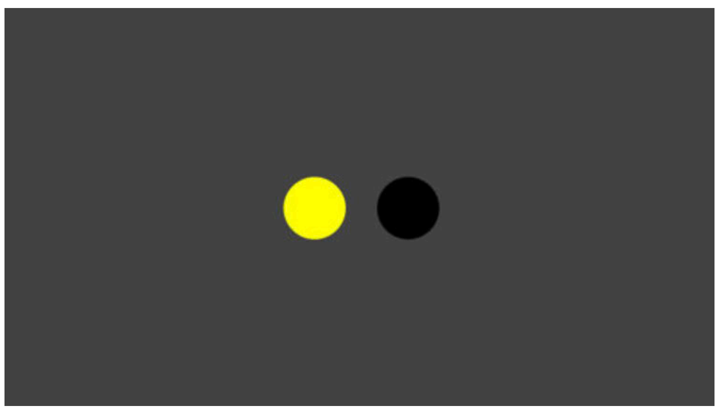

Figure 23: Reaction test (RT, n.d.)

The reaction test also consists of various test forms for various purposes within the field of reaction ability. For the assessment of the reaction performance of the participants within this study, the test form S5 is used. S5 is "the mean reaction time, which measures the reaction speed of the participants to relevant stimuli" (RT, n.d.). A representation of the reaction test is seen in Figure 23. Here, the participant must react whenever there is a yellow light stimulus + a sound, or a yellow light stimulus + a red light stimulus. The participants react by quickly shifting the index finger from the rest to the reaction key and again from the reaction to the rest key for the stimuli.

3.8 Statistical Analysis

This chapter provides a detailed description of the statistical analysis applied in this study. All the analyses are conducted using SPSS (Statistical Packages for Social Sciences) version 28. The graphs and charts were created using Microsoft (MS) Excel. The level of significance of the result was set to 95 % i.e., only results with a level of significance equal to or more than 95% would be considered statistically significant.

At first, the sample will be described by gender, age, and educational background. Age was categorized into four groups: 18 to 29 years, 30 to 39 years, 40 to 49 years, and 50 years and above. Education was categorized into 5 levels according to the Vienna Test System (VTS). They are; compulsory schooling not completed (less than nine years of school), completed compulsory schooling (9 to 10 years of school), completed vocational training (10 to 12 years of school), high school graduation with university entrance exam (12 to 13 years of school) and university or college degree. The variables: level of stability, cardiorespiratory endurance, concentration, and reaction will be measured by FMS-test, IPN-Test, Cognitron test and Reaction test respectively in the form of scores. These scores are described in the form of mean (M) and standard deviation (SD).

Repeated measures Analysis of Variance (rm ANOVA) was conducted to analyze the mean of the three groups. However, there is another step before using rm ANOVA for analysis i.e., to test if the assumptions for rm ANOVA are met. Firstly, data must be interval scaled and must be approximately normally distributed. There are various methods to check normality but in this study, the Shapiro-Wilk test was used as it is the most suitable method when the sample size is less than 50 (Mishra et al., 2019). Another requirement is the assumption for homogeneity of variance. Homogeneity of variance means that the variances of the different groups of participants in a study must come from populations with the same variances (Field, 2013). Levene's test is a statistical method used to check the homogeneity of variance in different groups or conditions (Levene H, 1960). In case this assumption is violated, alternative statistical methods must be considered. The Levene's test does not, however, check the homogeneity of the covariance matrices. Thus, Box's test was used to test the assumption of the homogeneity of the covariance matrices. This test draws a comparison between the variance-covariance matrices of the different groups (Field, 2013). As a further requirement for rm ANOVA, the assumption of sphericity was tested. This assumption is applicable to repeated measures that consist of three or more measuring time points. According to the assumption of sphericity, the variances in all the pairs of repeated measures must be the same. For testing this assumption, Mauchly's test was used (Nimon, 2012). In case the assumption of sphericity was violated, the correction was applied to the degrees of freedom for the repeated measures. Girden recommends that if the epsilon value is less than 0.75, the Greenhouse-Geisser correction should be applied, whereas if the epsilon value is greater than 0.75, the Huynh-Feldt correction should be applied (Girden, 1992).

Finally, a two-way repeated measures ANOVA was conducted. This method of analysis is used to examine the influence of multiple independent variables on a dependent variable while taking measurements across multiple time points or conditions (Schober & Vetter, 2018). With repeated measures multifactorial ANOVA, it is possible to analyze the main effects, the effects of each independent variable alone, and interactions, how the combination of independent variables works together to cause an effect.

3.9 Ethical Consideration

Participation of the apprentice nurses in this study was voluntary. The participants could cancel their participation at any given point of time without the obligation of stating any reasons. The apprentice nurses were informed about the purpose, the benefits, and the risks of the study. This information was given verbally as well as in the form of handouts. The purpose, benefits and risks of the project are described in elaborated form in the **declaration of consent** and **usage constructions** (s. Appendix II and III) which were handed out to the participants. The participation of the apprentice nurses in the study remains anonymous. Data that helps to identify the identity of the person were not collected. Data collected by the researcher from the participants were confidential and not given further to any third parties irrelevant to the study. Lastly, any type of harm, if any available through the participation in this study be it physical, psychological, or social was kept to an absolute minimum.

4 Results

4.1 Sample Description

In total 18 participants were included in the analysis. At the beginning of the study, there were 21 participants, but three participants dropped out before starting the study, stating health issues and time management issues. There were six participants in each group: the ExerCube group, the fitness-studio group, and the control group. Three more participants dropped out just before the third/last time point (t3) of data collection; one from the fitness studio group and two from the control group. So, in the end, there were 15 participants with a complete data set. Data from the last measurements from three participants were missing. But in order to complete the data set for 18 participants, the data for the last measurement of the three participants were imputed. This means the same data from t3 were taken as the value for t2 to maintain the sample size (N=18) needed in this study. Hereby, it was assumed that the values of FMS-Score, IPN-Score, Cognitron, and Reaction test scores of the three participants neither improved nor declined from the second time point to the third time point of measurement.

Gender

The overall distribution of gender in the study showed a higher number of females than males. 72.2 % (n=5) of the total participants were female, whereas 27.8 % (n=5) were male. The gender distribution is represented in a tabular form in Table 3.

Gender	Frequency	Percentage
Female	13	72.2
Male	5	27.8
Total	18	100

Table 3: Overall gender distribution

Furthermore, the distribution of gender in the three groups is shown in Table 4. The ExerCube group is found to have a high percentage of males (60%), whereas the control group is found to have a higher number of females (46.2%).

Group	Male		Female	
	N	%	N	%
ExerCube	3	60	3	23.1
Fitness studio	2	40	4	30.8
Control	0	0	6	46.2
Total	5	100	13	100

Table 4: Gender distribution in the three groups

Age

The mean age of the participants was found to be 27.39 years with a standard deviation (SD) of 8.59 years. The minimum age was found to be 18 years and the maximum age was found to be 49 years. There were no participants in the age category 50 years and above. The distribution of age among the participants showed high frequency in the category of 18 to 29 years old.

The distribution of age in the three groups is shown in table 5. The mean age of the ExerCube group is the highest at 30.33 years with an SD of 11.72 years. In the fitness-studio group, the mean age is 28.5 years with an SD of 7.15 years and in the control group, the mean age is found to be 23.33 years with an SD of 5.54 years.

Group	Mean	SD	MAX	MIN
ExerCube	30.33	11.72	49	19
Fitness-studio	28.5	7.15	42	22
Control	23.33	5.54	31	18

Table 5: Descriptive statistics of age in the three groups

Education:

Of all the participants, the highest number of participants had completed compulsory schooling (44.4%, n=8). Only one participant completed vocational training which corresponds to 5.6% of the total sample size. 22.2% (n=4) of the participants were high school graduates and lastly, 27.8% (n=5) of the participants had a university or college degree. The distribution of the education level of the participants is illustrated in the pie chart below.

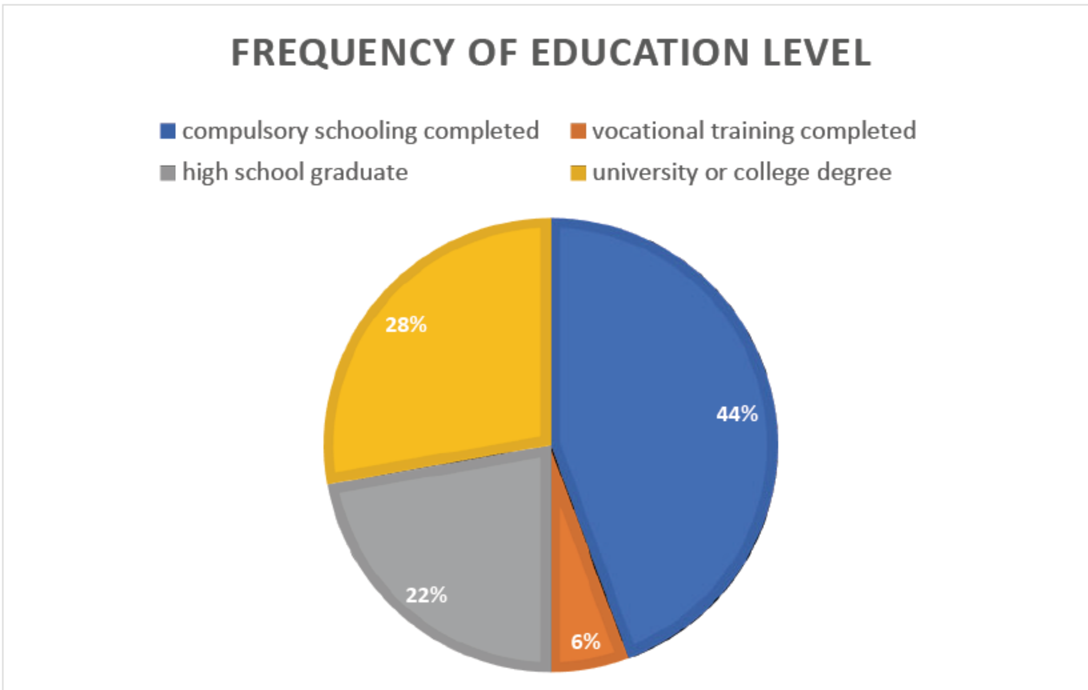

Figure 24: Distribution of education level among the participants

4.2 Functional Movement Screen Test

To answer the research question with the help of statistical analysis, the variable FMS score will be observed in this section.

Descriptive statistics

Table 1 summarizes the most important descriptive key figures of this variable within the groups. The mean values with standard deviation of each group at all three time points are listed in the table.

	Group	*M*	*SD*	*N*
Time point 1	ExerCube	10.83	1.602	6
	Fitness-studio	11.83	1.941	6
	Control	12.67	3.141	6
Time point 2	ExerCube	12.83	2.787	6
	Fitness-studio	12.33	2.582	6
	Control	13.50	2.739	6
Time point 3	ExerCube	13.67	1.633	6
	Fitness-studio	12.83	2.483	6
	Control	14.33	1.862	6

Table 6: Descriptive statistics for FMS score

Note: N = 18, M = mean value, SD = standard deviation.

From Table 1, it can be observed that there was an increase in the mean FMS test score of all three groups during the study. At time point 1, the group ExerCube had the lowest mean FMS test score in comparison to other groups. However, the group ExerCube had the highest increment in their mean FMS score from the first time point of measurement to the last time point of measurement. In the following paragraphs, it will be tested if assumptions for using repeated measures ANOVA are met. In case, assumptions are met, rm ANOVA will be used and it will be examined if the result of descriptive statistics is further confirmed by rm-ANOVA.

Assumption testing for ANOVA

The first assumption for normal distribution is tested by using the Shapiro-Wilk test. The results of the Shapiro-Wilk test are presented in Table 7. As seen in Table 7, normal distribution can be assumed as the results for the test are not statistically significant (>0.05) except for the p-value at the time point t1. This violation of assumption is very small and can, therefore, be ignored in this case (Öztuna et al., 2006).

	W	*df*	*p*
Time point 1 FMS	0.895	18	0.048
Time point 2 FMS	0.920	18	0.128
Time point 3 FMS	0.954	18	0.485

Table 7: Shapiro-Wilk test for FMS score

Note: N = 18, W = test statistics, p = significance

The second assumption of variance homogeneity is tested with the help of Levene's test. For the collected data of FMS score at three time points of measurement, there is an equality of error variances, because all of the p-values are not statistically significant. Table 8 summarizes the results of Levene's test.

	F	*df1*	*df2*	*p*
Time point 1 FMS	2.034	2	15	0.165
Time point 2 FMS	0.063	2	15	0.939
Time point 3 FMS	0.037	2	15	0.963

Table 8: Levene's test for FMS-score

Note: N=18, F = test statistics, df = degree of freedom, p = significance. Design: constant term + group + gender + age + time points of measurement

To test the homogeneity of the covariance matrices in a multivariate analysis, Box's test was carried out. Test of Equality of Covariance was present according to Box's test (p=0.383).

In the end, sphericity was tested using Mauchly's test. For the factor time (three time points of measurement), the assumption for sphericity was present (W=0.751, X^2 (2) = 3.429, p = 0.180, ε = 0.801). As a result, there was no correction needed.

Repeated measures two-way ANOVA

Two-way ANOVA with repeated measures was used for further analysis. This test examines the effect of the intervention on the value of FMS test scores of the participants. Here, the three groups are compared to each other over the three time points of measurement. As covariates, the factors of age and gender are taken into consideration. The result of the analysis is represented in the table below.

Factor	*F*	*df1*	*df2*	*p*	η_p^2
Measuring time point	3.907	2	26	0.033	0.231
Group	0.850	2	13	0.450	0.116
Gender	0.232	1	13	0.638	0.018
Age	1.224	1	13	0.289	0.086
Time point*Group	1.520	4	26	0.226	0.190
Time point*Gender	2.527	2	26	0.099	0.163
Time point*Age	2.425	2	26	0.278	0.094

Table 9: Two-way rm ANOVA for FMS test score

Note. N=18, F= test statistics, df= degree of freedom, p=significance

All the factors listed in the table are found to be statistically not significant i.e., all the p-values of the factors are above 0.05, except for the time point of measurement which is found to be statistically significant with a p-value of 0.033. The time point of measurement, however, shows a small effect (=0.231). Additionally, the interaction of group, gender and age with time points were included to see if these factors would be significant in case they interact with the time points. In this case, they were not found to be statistically significant.

4.3 Cardiorespiratory Ergometer Test

In this section, the IPN test scores for cardiorespiratory endurance will be observed for statistical analysis to answer the research question.

Descriptive statistics

Table 10 summarizes the most important descriptive key figures of this variable within the groups. It can be observed that the group ExerCube had the highest mean IPN score compared to other groups at time point t1, which gradually decreased till time point t3. The fitness-studio group remained with similar mean IPN scores from t1 to t3 with a slight decrease over time. The control group also showed an increase in their mean IPN score from t1 to t2, however, a slight decrease was observed from t2 to t3.

	Group	*M*	*SD*	*N*
Time point 1	ExerCube	1.583	0.3971	6
	Fitness-studio	1.483	0.3312	6
	Control	1.267	0.4590	6
Time point 2	ExerCube	1.444	0.3989	6
	Fitness-studio	1.417	0.3656	6
	Control	1.483	0.2041	6
Time point 3	ExerCube	1.333	0.2582	6
	Fitness-studio	1.411	0.2742	6
	Control	1.467	0.4502	6

Table 10: Descriptive statistics for IPN score

Note: N = 18, M = mean value, SD = standard deviation.

Assumption testing for ANOVA

Shapiro Wilk test showed that normal distribution can be assumed for the IPN scores of the participants. The test results are shown in Table 11. The results for the variables are not statistically significant, which is why a normal distribution can be assumed.

	W	*df*	*p*
Time point 1 IPN	0.932	18	0.212
Time point 2 IPN	0.951	18	0.445
Time point 3 IPN	0.931	18	0.205

Table 11: Shapiro-Wilk test for IPN score

Note: N = 18, W = test statistics, p = significance

The result of Levene's test is summarized in Table 12. Error variance homogeneity is present for all of the IPN scores in the three time points of measurement. This is because all the time points for the variable are not statistically significant.

	F	*df1*	*df2*	*p*
Time point 1 IPN	0.229	2	15	0.798
Time point 2 IPN	0.386	2	15	0.686
Time point 3 IPN	1.587	2	15	0.237

Table 12: Levene's test for IPN score

Note: N=18, F = test statistics, df = degree of freedom, p = significance. Design: constant term + Group + Gender + Age + time points of measurement

The condition of homogeneity of the covariance matrices can be assumed based on the result of Box’s test. This is assumed as the p-value (p = 0.724) is found to be greater than 0.05.

No sphericity is present for the factor, time points of measurement (W = 0.585, X^2 (2) = 6.443, p = 0.040, ε = 0.706). Girden (1992) recommends that for ε > 0.75, the Huynh-Feldt correction should be used, whereas for ε < 0.75, the Greenhouse-Geisser correction should be applied. According to the epsilon value, the Greenhouse-Geisser correction was used for further calculations in this case.

Repeated measures two-way ANOVA

Two-way ANOVA with repeated measures examines the effect of the intervention on the IPN scores of the participants. Here, all three groups are compared across the three time points of measurement in terms of the mean IPN test score. Gender and age were included as control variables in the testing. The results of the analysis are shown in Table 13. As observed in the table, all the factors are not statistically significant for the IPN scores.

Factor	*F*	*df1*	*df2*	*p*	η_p^2
Measuring time points	0.166	1.413	18.369	0.773	0.013
Group	0.110	2	13	0.897	0.017
Gender	0.238	1	13	0.634	0.018
Age	0.588	1	13	0.457	0.043
Time points*Group	0.398	2.826	18.369	0.745	0.058
Time points*Gender	0.103	1.413	18.369	0.834	0.008
Time points*Age	0.608	1.413	18.369	0.500	0.045

Table 13: Two-way rm ANOVA for IPN score

Note. N=18, F= test statistics, df= degree of freedom, p=significance

4.4 Cognitron Test

This section represents the statistical analysis for the Cognitron test scores of the participants in order to answer the research question.

Descriptive statistics

The important descriptive key figures of the Cognitron test within the groups are summarized in Table 14. Here, the ExerCube group and the control group are observed to have a distinct increase in their mean Cognitron score over time. The group ExerCube is found to have the highest increment in the mean Cognitron score in comparison to the other groups. Only a slight increase is observed in the mean Cognitron score of the fitness-studio group from the first time point of measurement to the last time point of measurement.

	Group	*M*	*SD*	*N*
Time point 1	ExerCube	57.83	9.600	6
	Fitness-studio	60.83	7.574	6
	Control	57	8.809	6
Time point 2	ExerCube	59.83	6.616	6
	Fitness-studio	60.67	13.277	6
	Control	58.67	13.367	6
Time point 3	ExerCube	66.67	8.406	6
	Fitness-studio	61.83	10.852	6
	Control	65.17	3.817	6

Table 14: Descriptive statistics for Cognitron score

Note: N = 18, M = Mean value, SD = Standard deviation.

Assumption testing for ANOVA

Shapiro-Wilk test showed that normal distribution can be assumed, as p-values are not statistically significant. The results of the Shapiro-Wilk test are shown in Table 15.

	W	*df*	*p*
Time point 1 COG	0.961	18	0.620
Time point 2 COG	0.979	18	0.942
Time point 3 COG	0.962	18	0.637

Table 15: Shapiro-Wilk test for Cognitron score

Note: N = 18, W = test statistics, p = significance

For the collected data from three time points of measurement for the Cognitron test, there is an equality of error variances as all of the p-values are not statistically significant. The results are summarized in Table 16.

	F	*df1*	*df2*	*p*
Time point 1 COG	0.076	2	15	0.927
Time point 2 COG	1.343	2	15	0.291
Time point 3 COG	0.448	2	15	0.647

Table 16: Levene's test for Cognitron score

Note: N=18, F = test statistics, df = degree of freedom, p = significance. Design: constant term + Group + Gender + Age + time points of measurement

The condition of homogeneity of the covariance matrices can be assumed, based on the result of the Box's test ($p = 0.283$) which is not statistically significant.

According to Mauchly's test, sphericity is present for the factor, time points of measurement ($W = 0.947$, $X^2 (2) = 0.648$, $p = 0.723$, $\varepsilon = 0.950$). For $\varepsilon > 0.75$, the Huynh-Feldt correction should be used. Accordingly, the Huynh-Feldt correction was used here for further calculations.

Repeated measures two-way ANOVA

Two-way ANOVA with repeated measures examines the effect of the intervention on the Cognitron score of the participants. Here, all three groups are compared across the three time points of measurement in terms of the mean Cognitron test score. Gender and age were included as control variables in the testing. The results of the analysis are shown in Table 17. According to the results in Table 17, the time points of measurement are statistically significant as p-value = 0.032 < 0.05. The interaction between time points of measurement and age is also found to be statistically significant as p-value = 0.046 < 0.05. Both the significant values, however, show a small effect.

Factor	*F*	*df1*	*df2*	*p*	η_p^2
Measuring time points	3.923	2	26	0.032	0.232
Group	0.440	2	13	0.653	0.063
Gender	0.907	1	13	0.358	0.065
Age	1.214	1	13	0.291	0.085
Time points*Group	1.401	4	26	0.261	0.177
Time points*Gender	2.425	2	26	0.108	0.157
Time points*Age	3.465	2	26	0.046	0.210

Table 17: Two-way rm ANOVA for Cognitron score

Note. N=18, F= test statistics, df= degree of freedom, p=significance

4.5 Reaction Test

In this section, the statistical analysis for the Reaction test score is observed to answer the research question.

Descriptive statistics

The important descriptive key figures of the Reaction test within the groups are shown in Table 18. As seen in the table, all three groups are observed to have a distinctive increment in their mean Reaction test score throughout the three time points of measurement. Although the ExerCube group had the lowest mean score at t1 in comparison to the other two groups, the group is observed to have the highest increment in the mean score from t1 to t3.

	Group	*M*	*SD*	*N*
Time point 1	ExerCube	48.50	10.784	6
	Fitness-studio	55.83	9.948	6
	Control	50	12.474	6
Time point 2	ExerCube	53.50	8.735	6
	Fitness-studio	59.17	10.008	6
	Control	52.67	8.641	6
Time point 3	ExerCube	53.83	12.687	6
	Fitness-studio	60.17	7.548	6
	Control	54.67	7.312	6

Table 18: Descriptive statistics for Reaction test score

Note: N = 18, M = Mean value, SD = Standard deviation.

Assumption testing for ANOVA

According to the Shapiro-Wilk test for the Reaction test scores, all three time points of measurement are found to be not statistically significant and therefore, a normal distribution can be assumed. The results of this test are shown in Table 19.

	W	*df*	*p*
Time point 1 RT	0.936	18	0.242
Time point 2 RT	0.981	18	0.955
Time point 3 RT	0.924	18	0.150

Table 19: Shapiro-Wilk test for Reaction test score

Note: N = 18, W = test statistics, p = significance

Error variance homogeneity is present according to Levene's test as the p-values for the variable are not statistically significant. Table 20 represents the results of Levene's test for Reaction test at the three time points of measurement.

	F	*df1*	*df2*	*p*
Time point 1 RT	0.801	2	15	0.467
Time point 2 RT	0.207	2	15	0.815
Time point 3 RT	0.331	2	15	0.723

Table 20: Levene's test for Reaction test score

Note: N=18, F = test statistics, df = degree of freedom, p = significance. Design: constant term + Group + Gender + Age + time points of measurement

Box's test showed that the condition of homogeneity of the covariance matrices can be assumed ($p = 0.212$).

According to Mauchly's test, no sphericity is present for the factor, time points of measurement ($W = 0.395$, X^2 $(2) = 11.137$, $p = 0.004$, $\varepsilon = 0.623$). Here for $\varepsilon < 0.75$, the

Greenhouse-Geisser correction should be applied. Accordingly, the Greenhouse-Geisser correction was used here for further calculations.

Repeated measures two-way ANOVA

Two-way ANOVA with repeated measures examines the effect of the intervention on the Reaction test score of the participants. Here, all three groups are compared across the three time points of measurement in terms of the mean Reaction test score. Here, gender and age were again included as control variables in the testing. All the factors are found to be not statistically significant. The results of the analysis are shown in Table 21.

Factor	*F*	*df1*	*df2*	*p*	η_p^2
Measuring time points	1.170	1.413	18.369	0.310	0.083
Group	1.055	2	13	0.376	0.140
Gender	0.875	1	13	0.367	0.063
Age	0.173	1	13	0.684	0.013
Time points*Group	0.344	2.493	16.202	0.758	0.050
Time points*Gender	1.700	1.246	16.202	0.214	0.116
Time points*Age	0.321	1.246	16.202	0.628	0.024

Table 21: Two-way rm ANOVA for Reaction test score

Note. N=18, F= test statistics, df= degree of freedom, p=significance

5 Discussion

5.1 Interpretation

Sociodemographic data

The descriptive statistics showed that more women took part in this study than men. This is, however, common in the profession of nursing, where the majority of the working professionals are women (Meleis, 2011). Most of the participants are in the age range of 18 to 29 years old. This is due to the fact that people normally start their vocational training school after finishing their high school education. The participants in the higher age range were mostly individuals who chose to change their career paths to nursing and were practicing another profession before that. The biggest proportion of the participants completed their compulsory school education. The rest of the participants had higher levels of education. This was expected as the requirement to start vocational training in nursing requires at least the completion of the compulsory school education i.e., nine to 10 years of school.

It can be observed that the ExerCube group has the highest number of male participants, whereas the control group has only female participants. Gender is one of the factors which may have a high impact on the result of the study. On the other side, it can be observed that the ExerCube group has more participants in a higher age range in comparison to the other two groups. The fitness-studio group had somewhat balanced age ranges whereas the control group had only young participants that were in a lower age range under 30 years. Age, too, is a factor to be considered which can have a high impact on the result of the study. Here, it is important to consider the fact that the assignment of the participants to one of the three groups was randomized and thus, the study was conducted in this manner.

Functional Movement Screen Test

The descriptive statistics for the FMS test results showed that there was a noticeable improvement in all three groups throughout the study. This was confirmed by the rm-ANOVA Test, where time points of measurement were found to be statistically significant. The improvements for the two groups: ExerCube and Fitness-studio were comprehensible. Here, it can be interpreted that the two groups trained for a certain period of time which showed positive effects on their FMS test score and thus on their core stability. This finding supports the result of studies by Fitzgerald et al. (2010), Sheehan & Katz (2013), and Shih et al. (2016), where the effect of exergaming on stability with different beneficiary groups in each study was investigated.

In this study, the effect size was, however, found to be small which indicates a small effect of the training sessions. There was also an improvement in the FMS test score on the control group, although not assigned any type of intervention to this group. For the control group, it has to be taken into consideration that the participants might have nevertheless practiced their own physical training or physical activities which would have influenced the FMS test score. Physical activity, as discussed in Chapter Two, is a very important aspect of the human body to remain healthy. From an ethical point of view, the control group are not, in any way, forbidden from any kind of physical training or activity that they choose to do outside of this project. Another factor that might have played an important role can be the age and gender of the participants. There were only female participants under the age of 30. This was, however, not confirmed by statistical analysis, as gender and age were not found to be statistically significant. Furthermore, the ExerCube group, fitness-studio group and control group do not differ significantly on the mean FMS-test score. This implies that the assignment of the participants to the three groups did not play a role in influencing the core stability. There is no significant interaction effect between the groups and the time points of measurement. That means there is also no combined effect between the group assignment of the participants and the time points of measurement.

Cardio-Ergometer Test

According to the descriptive statistics, there was no improvement in the IPN-test score of the participation. On the contrary, there was a slight deterioration in the mean test score of the participants throughout the study, except the test score of the control group from t1 to t2, where it showed a slight improvement. This inconsistency could have been due to various factors that influence endurance performance. In general, endurance performance is complex and does not depend only on physical activity, but rather is an interplay of various factors such as optimal training, nutrition intake, recovery, and environmental, biological and psychosocial factors (Konopka et al., 2022).

This effect in the IPN test scores was not confirmed by two-way ANOVA. Here, the three time points of measurement do not differ significantly. Thus, there was no noticeable improvement or deterioration in the endurance performance of the participants throughout the study. Similar results were also found in the study by Gao, Lee, et al. (2019) where no significant improvement in cardiovascular fitness over time was found between the exergaming group and the control group. Contrary to the findings of this study, Berg et al. (2022) stated in their study that exergaming increases cardiorespiratory fitness and can, therefore, be a good way to train cardiorespiratory endurance.

Furthermore, the ExerCube, fitness-studio and control groups also do not differ significantly in the mean IPN test score. That means the assignment of the group did not have an influence on the cardiorespiratory endurance. Gender and age do not seem to have any significant effects on the results. Furthermore, there is no significant interaction effect between the groups and time points of measurement. This means, there is no combined effect of group-assignment and time points of measurement on the mean IPN test score. There is also no significant interaction effect between time points of measurement and gender, or between time points of measurement and age.

Cognitron - Concentration Test

The descriptive statistics show that there was a distinctive improvement in the mean score of the ExerCube group, whereas the fitness-studio group remained similar, and the control group showed improvements only from t2 to t3. The improvement in the mean Cognitron score of the ExerCube group could be because there is a high level of concentration needed while training with ExerCube. As already explained in Chapter Two of this paper, the player must concentrate to perform the exercises correctly at the right time for higher scores, which might have motivated the player for higher concentration. The improvement shown by the control group from t2 to t3 could be just natural progression or due to involvement in their own physical activity or training.

The effect of the training sessions on the Cognitron score across three time points of measurement is confirmed statistically by two-way ANOVA as time points of measurement were found to be statistically significant. This implies that the improvement in the mean Cognitron score of the participants in the ExerCube group throughout the study was a result of the training sessions in ExerCube. This finding supports the study results of Ko et al. (2020) with ski exergames, where it was found that exergames with Virtual Reality (VR) content can enhance concentration skills in the player. Similarly, Y. Gao & Mandryk (2012) found in their study that "playing a casual exergame for ten minutes results in improved performance compared to a sedentary casual game on three cognitive tests that measure concentration". However, in a study by Russell (2009), no significant results were found for concentration, which contradicts the findings of this study.

In this study, it should be considered that although the result for time points of measurement was significant, the effect size was found to be small, which denotes a small effect of the training sessions. The ExerCube, fitness-studio and control groups do not differ significantly in the mean Cognitron test score. Gender and age alone do not seem to have any significant effect on the results. However, age interacting with time points of measurement was found to have a statistically significant interaction effect on the mean Cognitron score with a small effect size. The other interactions between time points of measurement and group, or measuring time and gender were not statistically significant.

Reaction Test

In the descriptive statistics, it was found that the ExerCube and the fitness-studio group made a considerable improvement in their mean reaction test score from t1 to t2, whereas there was just a slight improvement from t2 to t3. Here, it can be assumed that the ExerCube and fitness-studio group trained for the time from t1 to t2 which might have had an effect on their mean reaction test score. From time point t2 to t3, the participation rates of the participants in the ExerCube training dropped, where the improvement rate of the reaction test score also slowed down. The progression in the mean reaction test score of the control group remained consistent, which may be the result of natural progression.

The effect of the intervention on the mean Reaction test score, however, was not confirmed by the two-way rm ANOVA. The time points of measurement were found to be statistically non-significant which means that there was no noticeable improvement or deterioration in reaction skill of the participants throughout the study. Contrary to the findings of this study, Schoene et al. (2013) and Maillot et al. (2012) found in their study that exergaming improved reaction time in older adults. However, in both of these studies, no comparison or control groups were included. It is, therefore, difficult to establish through the findings of these studies whether exergaming enhanced the improvement in reaction time of the participants in comparison to sedentary videogames or traditional forms of exercise.

The ExerCube, fitness-studio and control groups did not differ significantly on the mean reaction test score. This implies that there was no difference between the mean of Reaction test scores among the three groups. Furthermore, there is no significant interaction effect between the groups and the time points of measurement. This means that there is no combined effect of the distribution of participants in groups and time points of measurement. Gender and age have no statistically significant effect on the observations.

5.2 Limitation

Like many other scientific studies, this study also has its limitations. Many factors contributed to reducing the quality of this study.

First of all, there was a significant decrease in participation in the ExerCube training session during the course of the study. The intervention of ExerCube training is a key component in this intervention-based study. Insufficient participation in the ExerCube training sessions raises the question if the observed changes are indeed a result of the training sessions. The participation rate of the training nurses taking part in this study was just around 60 % at the beginning of the study, which denotes mid-level participation. From further inquiry from the participants, the reasons for cancelling their ExerCube training sessions were mostly sickness, exam time, forgetting their scheduled appointment for the training and deployment to another care facility. At the end of the study, the participation rate further decreased to about 40 %. This certainly has a huge impact on the results of the study as the aim is to examine the impacts of ExerCube training sessions on physical and cognitive skills. Thus, participants not attending the ExerCube training sessions as planned i.e., two to three times per week for about 15 minutes or more, would less likely show the desired results. The low participation in the training sessions also raises the question of whether providing incentives for participation in the project would have increased participation in the training sessions.

Another limitation is the recruitment of participants which was quite difficult for this project. Even after advertising this project to the apprentice nurses in Alstertal Nursing School through many different ways like distributing hand-outs, Power-point presentations, and active contact with the apprentice nurses, there were only a little more than the required number of apprentice nurses who willingly agreed to participation in this study. There were about 92 apprentice nurses who were contacted for participation in this project. Out of them only 21 willingly agreed to participate.

As mentioned in Section Three of this thesis, three out of the 18 participants dropped out during the last phase of the study. Two participants from the control group and one from the fitness-studio group dropped out whereas there were no dropouts from the ExerCube group.

Data from 18 participants were needed according to the sample size calculation. Therefore, to fulfil this criterion, imputation was taken as a countermeasure. Here, the scores for all the tests in the third time point of measurement were the same values taken from the second time point of measurement. That means the last observation of the measurement was carried forward to the next measurement. This method was rather conservative as it was assumed that the value of the participants neither improved nor deteriorated. This also probably impacted the study's result because the sample size calculated was quite small. A small number of missing data can be relevant for such a small sample size. Furthermore, the effect sizes of significant statistical analyses were also found to be small.

A further limitation of this study is the information bias for the fitness studio and control group. The fitness studio group was offered to train in the fitness studio available on the premises of HzHG. Nevertheless, participants preferred to train in other fitness studios, where they already were a member. A full observation of the participants in the fitness studio group was, thus, not possible. It was not up to 100 % certain if they trained in the fitness studio two to three times a week as planned or skipped their training. Similarly in the control group, the participants were not assigned any kind of training. However, here it is also not up to 100 % sure if they were involved in any kind of physical activity outside of the study, which may have increased the scores of some of the participants. Furthermore, blinding was also not possible in conducting this study. Most of the participants in this study knew about each other. This might have influenced some kind of competition among the groups.

Besides, training time for the participants in this study could have been more flexible. Only two days with a certain frame of a few hours were provided as training hours for the participants in the ExerCube. There were only two ExerCubes and these were also to be used by customers outside of the study, which narrowed down the training hours available for the participants in this study.

Another limitation would be the accuracy of the test results of the participants in the time points of measurement. This is meant in a sense that the participants were sometimes tired from their school or work and would not seem to be completely focused during tests, whereas some days they were completely active and also fully concentrated. So basically, the results of the tests could also have been partly influenced by how the participants were feeling on that particular day.

In addition, there are also some costs tied together for the participants in such kind of study. At the very least, participants have to contribute a certain amount of time when participating in a study. Some participants may also feel a certain amount of discomfort disclosing their personal information (Guyll et al., 2003). As participants had to train two to three times every week, this study needed a dedicated amount of time from the participants which was not fulfilled multiple amounts of times during the study.

Finally, this project was also delayed due to various reasons. It was planned to start in March of 2022 which was delayed and could only be started in September of 2022. For this delay, there were various reasons. The COVID-19 pandemic also played a huge role in delaying the project, as delivery time for the ExerCubes was extended, and many appointments were thus shifted further. In addition to that, there were also some technical and management issues with the Vienna Test System which needed a certain time to be resolved.

5.3 Recommendation for Action

Considering the limitations of this study, the first and foremost recommendation for conducting this type of study would be to ensure active participation in the training by the study participants. Another way could be recruiting a higher number of participants than required. To ensure enough recruiting, such projects could be advertised in a higher capacity like recruiting participants from more nursing schools or considering other areas of professions as the beneficiaries.

The incentives provided in this study for ExerCube i.e., the cost-free training with the ExerCubes might not have been attractive enough to the participants. More brainstorming for what other types of incentives would be suitable for participation in the study can be done or researched to attract more participants. In addition, flexible training hours could help increase participation in training sessions. In this study, the training hours for the participants were very limited and thus many training sessions were also cancelled due to unmatching time for appointments and the training hours. If within the capacity, more ExerCubes should be available for training of the participants. However, here it is also important to take into consideration that ExerCube with its VR technology can be quite expensive product to buy and may not be easily available.

6 Conclusion

This thesis aimed to investigate the impact of ExerCube games on the physical (core stability and cardiovascular endurance) and cognitive (concentration and reaction) skills of apprentice nurses with the help of a three-armed randomized controlled trial. Sphery Racer of ExerCube was used as the game scenario for training sessions.

On one hand, the results suggest a significant influence of ExerCube training on the core stability and concentration for the time points of measurement. This implies a positive effect of ExerCube training on the core stability and concentration skills of the apprentice nurses who trained with ExerCube. On the other hand, the effect of ExerCube gaming did not show a significant influence on cardiovascular endurance and reaction skill, implying that there is no effect of ExerCube gaming on cardiovascular endurance and reaction skill. Additionally, the group factor (assignment of participants in ExerCube, Fitness-studio or control group) did not have an influence on the core stability, cardiovascular endurance, concentration, and reaction skills of the apprentice nurses. This inference has been made since the group factor did not show a significant influence on any of the physical or cognitive skills of the apprentice nurses. Furthermore, this was also confirmed by the rm ANOVA as the results showed no significant interactions. Factors like age and gender also had no significant influence on the physical and cognitive skills of the participant as it was not found to be statistically significant.

Despite this conclusion, the limitations of this study also need to be taken into consideration while answering the research question. One of the biggest drawbacks of this study was the small effect size and lack of participation in training sessions by the apprentice nurses which decreased further during the course of the study. This leads to the conclusion that in this setting, ExerCube training sessions might not have improved core stability and concentration in the apprentice nurses. Another important aspect to note is the decreasing participation in training sessions. Because this study is intervention-based, regular participation in the intervention is an essential aspect of investigating the effect of the intervention. A larger sample size with enough participation by the test group in the interventions must be ensured while carrying out such studies in the future.

7 Implications for HzHG

The ExerCube offers a variety of exercises in its first game, Sphery Racer. There are physical as well as cognitive challenges that the player has to face during the training session. Hereby, many physical skills (coordination, muscle strength, core stability) and cognitive skills (concentration, reaction) of the player come into play. Thus, the regular training sessions with ExerCube might be a useful tool to enhance the physical and cognitive skills of the player. The ExerCube is also easy to use. Its various functions make it easy for the player to set up the game according to his or her choice of difficulty and speed. ExerCube can also be considered as an inclusion-activity offer, as elderly people with wheelchairs and anyone who cannot stand for a longer period of time can easily train with ExerCube in a sitting position. At the end of the game, the player also gets feedback about the training performance after each session. This increases motivation among the players, which would help the players to improve and perform better for the next session.

Despite the advantages, the findings suggest that the difference between the ExerCube, Fitness-studio and control group was not significant in this study as there were no significant differences in the results of the three groups. This finding demonstrated that training with ExerCube did not show a better improvement of the physical and cognitive skills in comparison to the fitness studio or the control group. Therefore, it can be concluded that even though ExerCube is found to be a useful tool for physical and mental fitness, it is not the only choice for maintaining fitness or achieving a greater form of fitness in comparison to other traditional forms of exercise.

Nonetheless, it should be taken into consideration that the unique characteristic of ExerCube lies in its combination of gaming and fitness based on Virtual Reality technology creating an immersive experience for the user. This characteristic vastly differentiates ExerCube from the traditional forms of exercise or training in a fitness gym. Training sessions in ExerCubes are mostly perceived as a fun and motivating option for physical activity equipped with game scenarios. Thus, ExerCube has great potential to be offered as a leisure time physical activity for the seniors living at HzHG and for occupational health management to promote health and motivation among the users.

For further research in the context of HzHG, it may be interesting to know how training with ExerCube is perceived by the existing users who live on its premises or the employees. Observing the current situation regarding the usage of ExerCube among the residents, employees and external people, the gaming cube is rather highly accepted among elderly people. Feedback from existing users or new users on the use of ExerCube might be interesting and useful to further improve its implementation as a fitness and gaming device.

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Appendix I: Handout for Participants

Projektinformationen ExerCube:

1. Ziel: um zu untersuchen, ob das Training mit ExerCube-Spielen einen Einfluss auf die kognitiven und körperlichen Fähigkeiten hat
   Zielgruppe: Azubis über 18 Jahre alt
   Anzahl der Azubis: 18 Azubis ohne Verletzung oder Funktionsstörung (mindestens 9 Azubis fehlen noch).
   Projekt-Laufzeit: 6 Monate bis 2 Jahre voraussichtlich ab Dezember 2022
2. Methodik: Die Azubis werden nach dem Zufallsprinzip in drei Gruppen zugeteilt.
   - Die erste Gruppe trainiert mit ExerCube (1- bis 2-mal in der Woche)
   - Die zweite Gruppe im Fitnesszirkel im Haus Pfingstrose (1- bis 2-mal in der Woche)
   - Die dritte Gruppe macht kein Training

   Trainingszeiten für ExerCube: montags bis mittwochs ab 15 Uhr und freitags ab 14 Uhr.

   Trainingszeiten für Fitnesszirkel wird je nachdem nach Verfügbarkeit vereinbart.

   Die Gruppen wechseln sich nach jede sechs Monate damit jede Gruppe mit ExerCube dran ist.
3. Jede drei Monate führen wir Tests (FMS-Test, VTS-Test und Ergometer) durch, die körperlichen und kognitiven Fähigkeiten zu erfassen, dauert halbe bis eine Stunde.
4. Die erfassten Dateien sind anonym behandelt und ausgewertet.
5. Die Studie wird **im Rahmen der Arbeitszeiten** durchgeführt. Es gibt allerdings keine Aufwandsentschädigung.
6. Die Nutzung von ExerCube ist **kostenfrei** während der Studienteilnahme.
7. Die Teilnahme an der Studie ist **freiwillig.**
8. Weiter Informationen zu dem Projekt, Nutzungshinweise und Einverständniserklärung sind verfügbar.

Hinweise: Aus der Warnhinweise kann man hervorgehen, dass die ExerCube-Nutzung in einigen Fälle Schwindelgefühl verursachen kann. Jedoch ist ein/e Trainer/in während der ExerCube Sessions immer dabei.

Appendix II: Declaration of Consent

Declaration of consent

Project-partner:

Hospital zum Heiligen Geist

Mobil Health Insurance

Division Manager

Ole Behr

Project Manager

Nizar Müller

Student Trainee

Nina Gurung

1

Dear Participants,

In the following paragraphs you will find information to our project "ExerCube". We wish you to carefully read this informed consent form, and then to make a deliberate decision on whether to participate in this project. You can also ask the contact persons listed about anything related to this project that you don't understand. **The participation in this project will be valid as your working hours and managed in your working schedule.**

Project information

The ExerCube is an immersive fitness game setting that combines innovative software and hardware design with state-of-the-art training concepts. The player is surrounded by three walls running a virtual game with obstacles. It is controlled by the player's body movements, which are recorded by a tracking system and transmitted to the game. It can be played with different game scenarios and can be used for different trainings. The system uses Artificial Intelligence (AI) and adjusts speed or flow of the game is permanently to the fitness and gaming skills of the player, which creates an optimal training flow. This way, AI relieves the user from some of the decision-making process related to the game.

The aim of our study is to investigate whether training with ExerCube games has an impact on cognitive and physical skills in nursing trainees. In addition, with this new technology to train and play game at the same time, we would also like to motivate nursing trainees to take advantage of the exercise opportunities. The ExerCube is a new technology and by being able to test the application, we can investigate whether the use of ExerCube has a health-promoting effect on nursing trainees. Your assistance and feedbacks are very important to us, as it is the way for us to know if training with ExerCube games is fun and also promotes health.

The project duration is six months to two years. Participants will be randomly assigned to three groups. For the first six months, the first group will receive immediate access to ExerCube, the second group engages in some form of sport and the third group is expected not to engage in any kind of physical training. For the next six months, the second group will receive immediate access to ExerCube, the third group engages in some form of sport and the first group remains without physical training. The six months after this, the third group will receive access to ExerCube, the first group engages in some form of sport and the second group remain without physical training. The training sessions take place two times a week (at least 10-15 minutes per session) and are registered. But it is to be noted that there will not be any kind of pressure on the participant regarding their performance. During the project, the physical and cognitive abilities of the subjects are measured every three months with the help of tests. The physical abilities – flexibility and coordination are measured with Functional Movement Screen (FMS) tests, which consists of seven exercises that are performed by the participants. The score ranges from one to three points. The exercises are recorded, and each exercise is scored independently. And finally, endurance is also measured using an ergometer. The cognitive abilities of the participants will be tested using the Vienna Test System (WTS). This involves computerized performance tests to measure reaction and concentration skills in the participants. It is mostly used in various aspects of sport psychology and provides a valid and reliable testing procedure.

The project involves an interdisciplinary consortium with proven expertise in the fields of occupational health management, physiotherapy, project management and health sciences. **Note: Participation in this study is voluntary and there are neither advantages nor disadvantages by refusal of your participation. Your work-life will not be affected in any way.**

The partners in detail are,

- Hospital zum Heiligen Geist (https://www.hzhg.de/)
- Mobil health insurance (https://mobil-krankenkasse.de/)

HOSPITAL ZUM HEILIGEN GEIST
Lebensvielfalt für Senioren

Mobil KRANKENKASSE

Benefits and Risks

Your participation in this project will contribute to extend the knowledge regarding the use of immersive technologies in fitness and exercise to study the impacts on physical and cognitive skills. Thus, we are interested in learning whether training with ExerCube games improves physical and cognitive abilities.

Your participation in this project should not cause any significant difficulties. In rare cases, people react with the so-called simulator sickness, the symptoms of which correspond to those of motion sickness (nausea, dizziness). We remind you that you may ask for a break at any time during the study or terminate the session.

You hereby acknowledge that it is your responsibility to terminate the training should you experience symptoms of motion sickness and/or should they approach your tolerance level. In other case, should the medical staff or the trainer present at the sessions notice any kind of symptoms experienced by the participants, the training would also be terminated under the supervision of the medical staff or the trainer. Also, in case of acute indisposition, professional medical staff is at your disposal.

It must always be transparent to the user that he/she is communicating with an artificial intelligence, not with a human being.

For more detailed instructions, please refer to the document "Symptoms and Warnings".

Confidentiality, Exchange, and Publications

Your personal information and data collected during this project will be stored pseudonymously. Only the data necessary for the correct execution of the project will be collected. This information is as follows: Gender, demographic information, photo, audio or video recording, results of all experiments.

All information collected in this project will be kept confidential within the framework established by law. The data will be used for research purposes to achieve the scientific objectives of the project as described in this form. Data from this project may be published anonymously or pseudonymously in scientific reviews or shared with others in scientific discussions.

Photo and video-recordings

During the experiments some photo or video recordings will be made. We would like to use these for teaching, as well as for scientific presentations and publications. If you do not agree, the photos and videos would not be taken. In case you agree that your photos and videos be taken, but decide otherwise in the future, all video recordings and photos involving you will be destroyed immediately after you inform us, respecting the confidentiality.

Do you allow us to take photos and videos and store them along with your research data?

❑ Yes

❑ No

Data protection

The consortium, led by Hospital zum Heiligen Geist, undertake to comply with data protection in accordance with the and DSG-EKD (Church Law on Data Protection of the Evangelical Church in Germany). All data is processed in such a way that at no time is it possible to draw conclusions about an identifiable person.

After the project (for scientific purposes)

Also, after the completion of this project, the data and results collected could be further used in anonymised/pseudonymised form only for scientific purposes of research, teaching, reviews, or discussions.
Do you allow us to utilize your data further for scientific purposes in anonymised form after the completion of this project?

❑ Yes

❑ No

Your Rights

You have the following rights regarding the personal data concerning you:

- Right to access,
- Right to rectification or deletion,
- Right to restriction of processing,

- Right to data portability.

Right to withdrawal

As mentioned previously, your participation in this project is voluntary. You can withdraw from the study at any time without giving reasons and without consequences. If you answer questions as part of the study (e.g., as part of a questionnaire), you have the option to omit any questions you do not wish to answer.

In case you withdraw from the study, do you want all documents and files created regarding your participation to be destroyed?

❑ Yes

❑ No

Note: The revocation of the consent to the processing of personal data can only refer to the further use of data and cannot be made retroactive for scientific papers or research that has already been published.

Right to complain to a supervisory authority

You also have the right to complain to a data protection supervisory authority about our processing of your personal data.

The supervisory authority directly responsible for us is:

Der Beauftragte für den Datenschutz der Evangelischen Kirche in Deutschland

[redacted]

E-Mail: [redacted]

Internet: https://datenschutz.ekd.de

Contact

If you have any questions, please contact HzHG or the following contact persons.

Division-manager: Ole Behr [redacted] Hospital zum Heiligen Geist Hinsbleek 11 22391 Hamburg	Project-manager: Nizar Müller [redacted] Hospital zum Heiligen Geist Hinsbleek 11 22391 Hamburg	Student-trainee of the project: Nina Gurung [redacted]

Declaration of consent by the participant

I, ____ (Name in capital letters) declare, that I have read this form and understand the nature and purpose of my participation in this project. I have received answers to all my questions about the study.

I, hereby, consent to participate in this project.

Signature of Participant: ______________________________

Place and Date: ______________________________

Appendix III: Usage Instructions for ExerCube

Hospital zum Heiligen Geist (HzHG)

Division: Occupational Health Management

Usage instructions for ExerCube

Symptoms & Warnings

Division Manager

Ole Behr

Project Manager

Nizar Müller

Student Trainee

Nina Gurung

7

Preface

The ExerCube is an immersive fitness game setting that combines innovative software and hardware design with state-of-the-art training concepts. The player is surrounded by three walls running a virtual game with obstacles. It is controlled by whole-body movements, which are recorded by a tracking system and transmitted to the game. The difficulty is permanently adjusted to the fitness and gaming skills of the player, which creates an optimal training flow. The ExerCube offers a gaming experience in single or multiplayer mode. It can be played with different game scenarios and can be used for different trainings. The experienced content can cause different emotions and make the body react as if the experience was real. Potential dangers are rare, can nevertheless arise from negative reactions of the player to the game events. Since ExerCube is a new technology, there is a possibility that other as yet unknown risks may be associated with its use.

Contents

Following three sections provide general instructions for the usage of ExerCube. These are divided into:

1. Before use of ExerCube (preparatory measures)

2. Exclusion criteria (circumstances that exclude from ExerCube use)

3. After use of ExerCube (post-processing)

To reduce the risk of incidents when using ExerCube, the following points should be observed:

1. Before use of ExerCube (preparatory measures)

i. Health aspects

If the individual has a history of medical conditions or physical/psychological symptoms of illness, a physician should be consulted before using ExerCube. The following cases require medical advice:

- Heart diseases
- Physical impairments that interfere with the safe involvement in physiological activities
- Psychological impairments, such as anxiety disorders, post-traumatic stress disorder, claustrophobia, ...

ii. Susceptibility to symptoms

There is a possibility that activities that take place prior to use of ExerCube may increase the risk of onset of those symptoms that can preclude the use of ExerCube. Therefore, it is important to consider what kind of activity the individual was engaged in, prior to using ExerCube. This way, a break can be scheduled before beginning the use of ExerCube, if necessary.

iii. Safe surrounding

➢ Preparation of the Play Area:
Ensure that the play area (the Cube) provides a firm and safe surface and is free of distracting factors such as, carpet edges, pets running around, furnishings (chairs, plants, shelves, etc...), other objects.

➢ Equipment and Setting:
Conscious use of all accessories necessary for operation - heart rate sensor, motion tracker. Settings such as duration, type of exercises (beginners, intermediate, advance) should already be chosen before the use of ExerCube.

➢ Supervisor:
If applicable, set up a person to watch that the play area is protected from disruptive factors and to guide the player during the use of ExerCube.

2. Exclusion criteria (circumstances that exclude from ExerCube use)

The use of ExerCube enables the player to train and exercise in a virtual world. The use of ExerCube may although involve risks. These risks should be known to all the people that are involved in its operation.

Symptoms listed below are to be understood as criteria that preclude use of ExerCube if they occur before or during use.

Symptoms	Descriptions
Exhaustion/Drowsiness	Staying in virtual environment of ExerCube could be cognitively and physically demanding. Physical movement during training can make the users exert themselves. If there are signs of exhaustion, the use of ExerCube is not recommended in order to prevent carelessness-related accidents.
Motion-Sickness	Motion sickness" is the situation when the player has the visual perception that he is moving within the ExerCube experience, but his body does not confirm this perception. This can result in symptoms that are familiar under the term motion sickness. The symptoms include headache, sweating, nausea, dizziness, pallor, hyperventilation. In case these symptoms occur, the use of ExerCube is generally not recommended.

	But the occurrence of motion sickness can possibly be counteracted by keeping the duration of the game short at the beginning and, at the first signs of the aforementioned symptoms, closing the eyes, becoming aware of one's physical surroundings, taking a deep breath and trying again. Depending on the development, the duration of the experience can then be increased.
Epilepsy / seizures / involuntary movements	Similar to television, the player is also exposed to visual effects in VR when using ExerCube. The so-called photosensitive epilepsy can be caused by flickering lights and flashes of light. (Photosensitive epilepsy belongs to the group of reflex epilepsies, which can generally be triggered by visual and auditory stimuli, but also by cognitive or emotional processes).
Medications	Medication taken may have a negative effect on the user's condition and may increase symptoms triggered by the experience of ExerCube
Fainting	If there are signs of fainting, stop the procedure immediately
Visual impairments: • eye or muscle twitching • Blurred vision • Double vision • Comparable phenomena	In case of impaired vision, the use of ExerCube is generally not recommended.
Disorder of Hand-Eye coordination	Whether reduced coordination ability is an exclusion criterion depends on the severity of the disorder.
Medical devices	Medical consultation required when the user is wearing, • cardiac pacemakers • Hearing aids

Attention! If pain occurs in muscles, joints, neck, hands or skin during the use, use of ExerCube should be discontinued. If the symptoms persist, further use should be discontinued, and a physician should be contacted.

3. After use of ExerCube (post-processing)

i) Controlled termination of use of ExerCube

If a person experiences an immersive experience for the first time and for several minutes while using it, it must be taken into account that each person processes such an immersive experience differently.
Therefore, for a smooth completion of the ExerCube experience, it may be helpful, especially in the beginning, for the player to be oriented to someone who is well versed in ExerCube use.
This approach is especially recommended if the player has little or no prior experience with ExerCube.

ii) Lingering of symptoms

Symptoms listed above, that may occur as a result of use of ExerCube may continue and intensify until after use. If symptoms have occurred during the ExerCube experience, physically, visually and/or mentally demanding activities should not be pursued afterwards.
Appropriate aftercare - such as scheduled rest - is advised until the respective symptoms have subsided. The ExerCube should not be used until any symptoms have completely subsided for several hours.

Appendix IV: Syntax for Statistical Analysis in SPSS

```
FREQUENCIES VARIABLES=Gender Education
  /STATISTICS=RANGE MEAN
  /BARCHART FREQ
  /ORDER=ANALYSIS.

FREQUENCIES VARIABLES=Age
  /NTILES=4
  /STATISTICS=STDDEV RANGE MINIMUM MAXIMUM MEAN MEDIAN
  /HISTOGRAM NORMAL
  /ORDER=ANALYSIS.

GLM M1_FMS M2_FMS M3_FMS BY Group WITH Age Gender
  /WSFACTOR=time 3 Simple(1)
  /METHOD=SSTYPE(3)
  /PLOT=PROFILE(Group*time time*Group) TYPE=LINE ERRORBAR=NO
MEANREFERENCE=NO YAXIS=AUTO
  /PRINT=DESCRIPTIVE ETASQ HOMOGENEITY
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=time
  /DESIGN=Age Gender Group.

EXAMINE VARIABLES=M1_FMS M2_FMS M3_FMS
  /PLOT BOXPLOT STEMLEAF NPPLOT
  /COMPARE GROUPS
  /STATISTICS DESCRIPTIVES
  /CINTERVAL 95
  /MISSING LISTWISE
  /NOTOTAL.
```

```
DATASET ACTIVATE DataSet1.
GLM M1_Ergo M2_Ergo M3_Ergo BY Group WITH Age Gender
  /WSFACTOR=time 3 Simple(1)
  /METHOD=SSTYPE(3)
  /PLOT=PROFILE(Group*time time*Group) TYPE=LINE ERRORBAR=NO
MEANREFERENCE=NO YAXIS=AUTO
  /PRINT=DESCRIPTIVE ETASQ HOMOGENEITY
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=time
  /DESIGN=Age Gender Group.

EXAMINE VARIABLES=M1_Ergo M2_Ergo M3_Ergo
  /PLOT BOXPLOT STEMLEAF NPPLOT
  /COMPARE GROUPS
  /STATISTICS DESCRIPTIVES
  /CINTERVAL 95
  /MISSING LISTWISE
  /NOTOTAL.

GLM M1_COG M2_COG M3_COG BY Group WITH Age Gender
  /WSFACTOR=time 3 Simple(1)
  /METHOD=SSTYPE(3)
  /PLOT=PROFILE(Group*time time*Group) TYPE=LINE ERRORBAR=NO
MEANREFERENCE=NO YAXIS=AUTO
  /PRINT=DESCRIPTIVE ETASQ HOMOGENEITY
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=time
  /DESIGN=Age Gender Group.

EXAMINE VARIABLES=M1_COG M2_COG M3_COG
  /PLOT BOXPLOT STEMLEAF NPPLOT
```

```
  /COMPARE GROUPS
  /STATISTICS DESCRIPTIVES
  /CINTERVAL 95
  /MISSING LISTWISE
  /NOTOTAL.

GLM M1_RT M2_RT M3_RT BY Group WITH Age Gender
  /WSFACTOR=time 3 Simple(1)
  /METHOD=SSTYPE(3)
  /PLOT=PROFILE(Group*time time*Group) TYPE=LINE ERRORBAR=NO
MEANREFERENCE=NO YAXIS=AUTO
  /PRINT=DESCRIPTIVE ETASQ HOMOGENEITY
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=time
  /DESIGN=Age Gender Group.

EXAMINE VARIABLES=M1_RT M2_RT M3_RT
  /PLOT BOXPLOT STEMLEAF NPPLOT
  /COMPARE GROUPS
  /STATISTICS DESCRIPTIVES
  /CINTERVAL 95
  /MISSING LISTWISE
  /NOTOTAL.
```

Appendix V: Supplement tables for Assumption Testing and rm ANOVA

Functional Movement Screen test

Box's Test of Equality of Covariance Matrices[a]

Box's M	18.319
F	1.069
df1	12
df2	1090.385
Sig.	.383

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.

a. Design: Intercept + Age + Gender + Group
Within Subjects Design: time

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
M1_FMS	.223	18	.018	.895	18	.048
M2_FMS	.156	18	.200*	.920	18	.128
M3_FMS	.145	18	.200*	.954	18	.485

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Levene's Test of Equality of Error Variances[a]

	F	df1	df2	Sig.
M1_FMS	2.034	2	15	.165
M2_FMS	.063	2	15	.939
M3_FMS	.037	2	15	.963

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Age + Gender + Group
Within Subjects Design: time

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
time	.751	3.429	2	.180	.801	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept + Age + Gender + Group
Within Subjects Design: time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
time	Sphericity Assumed	14.096	2	7.048	3.907	.033	.231
	Greenhouse-Geisser	14.096	1.602	8.800	3.907	.044	.231
	Huynh-Feldt	14.096	2.000	7.048	3.907	.033	.231
	Lower-bound	14.096	1.000	14.096	3.907	.070	.231
time * Age	Sphericity Assumed	4.850	2	2.425	1.344	.278	.094
	Greenhouse-Geisser	4.850	1.602	3.028	1.344	.277	.094
	Huynh-Feldt	4.850	2.000	2.425	1.344	.278	.094
	Lower-bound	4.850	1.000	4.850	1.344	.267	.094
time * Gender	Sphericity Assumed	9.118	2	4.559	2.527	.099	.163
	Greenhouse-Geisser	9.118	1.602	5.692	2.527	.113	.163
	Huynh-Feldt	9.118	2.000	4.559	2.527	.099	.163
	Lower-bound	9.118	1.000	9.118	2.527	.136	.163
time * Group	Sphericity Assumed	10.967	4	2.742	1.520	.226	.190
	Greenhouse-Geisser	10.967	3.204	3.423	1.520	.238	.190
	Huynh-Feldt	10.967	4.000	2.742	1.520	.226	.190
	Lower-bound	10.967	2.000	5.484	1.520	.255	.190
Error(time)	Sphericity Assumed	46.902	26	1.804			
	Greenhouse-Geisser	46.902	20.824	2.252			
	Huynh-Feldt	46.902	26.000	1.804			
	Lower-bound	46.902	13.000	3.608			

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	59.620	1	59.620	13.082	.003	.502
Age	5.577	1	5.577	1.224	.289	.086
Gender	1.059	1	1.059	.232	.638	.018
Group	7.748	2	3.874	.850	.450	.116
Error	59.248	13	4.558			

IPN Test (Cardiorespiratory ergometer test)

Box's Test of Equality of Covariance Matrices[a]

Box's M	12.500
F	.729
df1	12
df2	1090.385
Sig.	.724

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.

a. Design: Intercept + Age + Gender + Group
Within Subjects Design: time

Levene's Test of Equality of Error Variances[a]

	F	df1	df2	Sig.
M1_Ergo	.229	2	15	.798
M2_Ergo	.386	2	15	.686
M3_Ergo	1.587	2	15	.237

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Age + Gender + Group
Within Subjects Design: time

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
M1_Ergo	.147	18	.200*	.932	18	.212
M2_Ergo	.151	18	.200*	.951	18	.445
M3_Ergo	.131	18	.200*	.931	18	.205

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
time	.585	6.443	2	.040	.706	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept + Age + Gender + Group
Within Subjects Design: time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
time	Sphericity Assumed	.009	2	.005	.166	.848	.013
	Greenhouse-Geisser	.009	1.413	.007	.166	.773	.013
	Huynh-Feldt	.009	2.000	.005	.166	.848	.013
	Lower-bound	.009	1.000	.009	.166	.690	.013
time * Age	Sphericity Assumed	.034	2	.017	.608	.552	.045
	Greenhouse-Geisser	.034	1.413	.024	.608	.500	.045
	Huynh-Feldt	.034	2.000	.017	.608	.552	.045
	Lower-bound	.034	1.000	.034	.608	.450	.045
time * Gender	Sphericity Assumed	.006	2	.003	.103	.902	.008
	Greenhouse-Geisser	.006	1.413	.004	.103	.834	.008
	Huynh-Feldt	.006	2.000	.003	.103	.902	.008
	Lower-bound	.006	1.000	.006	.103	.753	.008
time * Group	Sphericity Assumed	.044	4	.011	.398	.808	.058
	Greenhouse-Geisser	.044	2.826	.016	.398	.745	.058
	Huynh-Feldt	.044	4.000	.011	.398	.808	.058
	Lower-bound	.044	2.000	.022	.398	.679	.058
Error(time)	Sphericity Assumed	.719	26	.028			
	Greenhouse-Geisser	.719	18.369	.039			
	Huynh-Feldt	.719	26.000	.028			
	Lower-bound	.719	13.000	.055			

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	.670	1	.670	6.016	.029	.316
Age	.065	1	.065	.588	.457	.043
Gender	.027	1	.027	.238	.634	.018
Group	.024	2	.012	.110	.897	.017
Error	1.448	13	.111			

Cognitron test

Box's Test of Equality of Covariance Matrices[a]

Box's M	20.434
F	1.192
df1	12
df2	1090.385
Sig.	.283

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.

a. Design: Intercept + Age + Gender + Group
Within Subjects Design: time

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
M1_COG	.160	18	.200*	.961	18	.620
M2_COG	.120	18	.200*	.979	18	.942
M3_COG	.125	18	.200*	.962	18	.637

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Levene's Test of Equality of Error Variances[a]

	F	df1	df2	Sig.
M1_COG	.076	2	15	.927
M2_COG	1.343	2	15	.291
M3_COG	.448	2	15	.647

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Age + Gender + Group
Within Subjects Design: time

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

					Epsilon[b]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
time	.947	.648	2	.723	.950	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept + Age + Gender + Group
Within Subjects Design: time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
time	Sphericity Assumed	324.921	2	162.461	3.923	.032	.232
	Greenhouse-Geisser	324.921	1.900	171.002	3.923	.035	.232
	Huynh-Feldt	324.921	2.000	162.461	3.923	.032	.232
	Lower-bound	324.921	1.000	324.921	3.923	.069	.232
time * Age	Sphericity Assumed	287.046	2	143.523	3.465	.046	.210
	Greenhouse-Geisser	287.046	1.900	151.069	3.465	.049	.210
	Huynh-Feldt	287.046	2.000	143.523	3.465	.046	.210
	Lower-bound	287.046	1.000	287.046	3.465	.085	.210
time * Gender	Sphericity Assumed	200.861	2	100.431	2.425	.108	.157
	Greenhouse-Geisser	200.861	1.900	105.711	2.425	.112	.157
	Huynh-Feldt	200.861	2.000	100.431	2.425	.108	.157
	Lower-bound	200.861	1.000	200.861	2.425	.143	.157
time * Group	Sphericity Assumed	232.102	4	58.025	1.401	.261	.177
	Greenhouse-Geisser	232.102	3.800	61.076	1.401	.264	.177
	Huynh-Feldt	232.102	4.000	58.025	1.401	.261	.177
	Lower-bound	232.102	2.000	116.051	1.401	.281	.177
Error(time)	Sphericity Assumed	1076.849	26	41.417			
	Greenhouse-Geisser	1076.849	24.701	43.595			
	Huynh-Feldt	1076.849	26.000	41.417			
	Lower-bound	1076.849	13.000	82.835			

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	2891.388	1	2891.388	46.012	<.001	.780
Age	76.290	1	76.290	1.214	.291	.085
Gender	56.987	1	56.987	.907	.358	.065
Group	55.325	2	27.662	.440	.653	.063
Error	816.918	13	62.840			

Reaction test

Box's Test of Equality of Covariance Matrices[a]

Box's M	22.279
F	1.300
df1	12
df2	1090.385
Sig.	.212

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.

a. Design: Intercept + Age + Gender + Group
Within Subjects Design: time

Levene's Test of Equality of Error Variances[a]

	F	df1	df2	Sig.
M1_RT	.801	2	15	.467
M2_RT	.207	2	15	.815
M3_RT	.331	2	15	.723

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Age + Gender + Group
Within Subjects Design: time

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
M1_RT	.161	18	.200*	.936	18	.242
M2_RT	.106	18	.200*	.981	18	.955
M3_RT	.175	18	.149	.924	18	.150

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

					Epsilon[b]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
time	.395	11.137	2	.004	.623	.869	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept + Age + Gender + Group
Within Subjects Design: time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
time	Sphericity Assumed	83.142	2	41.571	1.170	.326	.083
	Greenhouse-Geisser	83.142	1.246	66.709	1.170	.310	.083
	Huynh-Feldt	83.142	1.739	47.823	1.170	.322	.083
	Lower-bound	83.142	1.000	83.142	1.170	.299	.083
time * Age	Sphericity Assumed	22.824	2	11.412	.321	.728	.024
	Greenhouse-Geisser	22.824	1.246	18.313	.321	.628	.024
	Huynh-Feldt	22.824	1.739	13.128	.321	.699	.024
	Lower-bound	22.824	1.000	22.824	.321	.581	.024
time * Gender	Sphericity Assumed	120.819	2	60.410	1.700	.202	.116
	Greenhouse-Geisser	120.819	1.246	96.939	1.700	.214	.116
	Huynh-Feldt	120.819	1.739	69.495	1.700	.207	.116
	Lower-bound	120.819	1.000	120.819	1.700	.215	.116
time * Group	Sphericity Assumed	48.919	4	12.230	.344	.846	.050
	Greenhouse-Geisser	48.919	2.493	19.625	.344	.758	.050
	Huynh-Feldt	48.919	3.477	14.069	.344	.821	.050
	Lower-bound	48.919	2.000	24.459	.344	.715	.050
Error(time)	Sphericity Assumed	923.817	26	35.531			
	Greenhouse-Geisser	923.817	16.202	57.017			
	Huynh-Feldt	923.817	22.601	40.875			
	Lower-bound	923.817	13.000	71.063			

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	1075.915	1	1075.915	13.630	.003	.512
Age	13.658	1	13.658	.173	.684	.013
Gender	69.082	1	69.082	.875	.367	.063
Group	166.622	2	83.311	1.055	.376	.140
Error	1026.217	13	78.940			

Declaration of Academic Honesty

Hereby, I declare that I have composed the presented master thesis independently on my own and without any other resource than the ones indicated. All thoughts taken directly or indirectly from external sources are properly denoted as such.

Hamburg, 30. September 2023

[redacted]

Nina Gurung