IMPLEMENTING SHARED DECISION-MAKING FOR RETURNING TO PLAY SPORTS AFTER AN INJURY USING THE ANALYTIC HIERARCHY PROCESS (AHP) IN A WEB APPLICATION

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ABSTRACT

IMPLEMENTING SHARED DECISION-MAKING FOR RETURNING TO PLAY SPORTS AFTER AN INJURY USING THE ANALYTIC HIERARCHY PROCESS (AHP) IN A WEB APPLICATION

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Return to sport after an injury is a complex decision-making process taken by multiple decision-makers by considering multiple criteria. Biological and functional recoveries are the main factor of the decision. However, since this decision will affect athletes' career paths, psychological readiness of athletes is required to be a crucial part of the decision. This thesis investigates how to implement a shared decision-making model with a developed Return to Sport Decision Aid Tool by using Analytic Hierarchy Process (AHP) which reveals sociological and psychological effects of return to sport process on athletes. To understand athletes' perspectives and determine their preferences, two different scenarios were created. A total of 20 athletes from different disciplines and sports level participated in the study. The results show that facing the same scenario, athletes' preferences and priority degrees are different from each other and in different circumstances (Scenario1 and Scenario2), athletes can prioritize different criteria. Final decision can change according to athletes' preferences. While in Scenario1, 25% of athletes decide to play despite an injury by opposing healthcare professional's recommendation, in Scenario2, 10% of athletes do not feel ready to return to sport although healthcare professional approves his/her biomedical and functional healing. 75% of athletes indicate that the application prepares them to make a better decision and offer a reliable method for decision-making. According to results of the study, sociological and psychological factors are undeniable effects on return to sports decision and shared decision-making can be applied as a consensus model.

Keywords: Shared decision making, Analytic Hierarchy Process (AHP), decision-making, return to sports, decision aid application

ÖZ

WEB TABANLI BİR UYGULAMA İLE SAKATLIK SONRASI SPORA DÖNÜŞ İÇİN ANALİTİK HİYERARŞİ SÜRECİNİ KULLANARAK ORTAK KARAR VERME MODELİNİ GERÇEKLEŞTİRME

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Sakatlık sonrası spora dönüş, birden fazla kriterin, birçok karar verici tarafından göz önünde bulundurularak alındığı kompleks bir karar verme sürecidir. Biyolojik ve fonksiyonel iyileşmeler kararın temel faktörüdür. Ancak, bu karar sporcuların kariyer hayatını etkileyeceğinden, sporcuların psikolojik olarak kendilerini hazır hissetmeleri kararın önemli bir parçası olmasını gerektirmektedir. Bu tez, spora geri dönüş sürecinin sporcular üzerindeki sosyolojik ve psikolojik etkilerini ortaya koyan Analitik Hiyerarşi Süreci (AHP) kullanılarak geliştirilmiş Spora Dönüş Karar Yardım Aracı ile ortak bir karar verme modelinin nasıl uygulanacağını araştırmaktadır. Sporcuların bakış açılarını anlamak ve tercihlerini belirlemek için iki farklı senaryo oluşturulmuştur. Çalışmaya farklı disiplinlerden ve spor seviyesinden toplam 20 sporcu katılmıştır. Sonuç, aynı senaryo ile karşılaşan sporcuların tercihlerinin ve önem derecelerinin birbirinden farklı olduğunu ve farklı koşullarda (Senaryo1 ve Senaryo2), sporcuların farklı kriterleri önceliklendirebileceğini göstermektedir. Son karar sporcuların tercihlerine göre değişkenlik gösterebilir. Senaryo1'de sporcuların %25'i sağlık uzmanının tavsiyesine uymayarak sakatlığa rağmen oynamaya karar verirken, Senaryo2'de sporcuların %10'u sağlık uzmanının biyomedikal ve fonksiyonel iyileşmesine onay vermesine rağmen kendini spora geri dönmeye hazır hissetmemiştir. Sporcuların %75'i uygulamanın onları daha iyi bir karar vermeye hazırladığını ve uygulamanın karar verme için güvenilir bir yöntem olduğunu belirtmiştir. Çalışmanın sonuçlarına göre, sosyolojik ve psikolojik faktörlerin spora dönüş kararı üzerinde yadsınamaz etkileri vardır ve ortak karar verme, uzlaşma modeli olarak uygulanabilir.

Anahtar Sözcükler: Paylaşımlı karar verme, Analitik Hiyerarşi Süreci (AHP), karar verme, spora dönüş, karar yardım uygulaması

To My Family

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LIST OF ABBREVIATIONS

RTP	Return to Play
RTS	Return to Sport
PCDM	Patient-centered Decision Making
SDM	Shared Decision Making
MCDA	Multiple-Criteria Decision Analysis
MCAP	Multi-Criterion Aggregation Procedure
DM	Decision Maker
DMs	Decision Makers
AHP	Analytic Hierarchy Process
CR	Consistency Ratio
CI	Consistency Index
RI	Random Index
DNA	Deoxyribonucleic acid
IPDAS	The International Patient Decision Aids Collaboration
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
MAVT	Multi-attribute Value Theory
SMART	Simple Multi-attribute Rating Technique
MAUT	Multi-attribute Utility Theory
CRITIC	Criteria Importance Through Inter-criteria Correlation
WS	Weighted Sum
CSS	Cascading Style Sheet
MSSQL	Microsoft SQL Server

CHAPTER 1

1. INTRODUCTION

Sport injuries can occur anywhere on the body and can be caused by improper training, accidents, overtraining or inappropriate equipment choice. These injuries are categorized in two, acute traumatic and overuse (chronic) injuries. While the first type occurs after heavy blow, fall or force, chronic injuries happen over time after repetitive training. Regardless of the injury types, the first question that comes to mind is "When can I return to play again?".

Return to play (RTP) decision requires medical approval of an athlete for full involvement in the sport without any limitations and takes some time according to kind of the injury. For the healing process of the athlete, all injury types consist of three common recovery steps; biological, functional and psychological (mental) (Jaen & Garcia, 2017). These are the core criteria which determine whether an injured athlete can be allowed to RTP in sport. In order to answer the purpose of return to sport (RTS) in therapeutic process, athletes should be in-good state in terms of physical, mental and functional conditions (Jaen & Garcia, 2017).

Biological factors like age, gender and DNA are personally identifiable. Each athlete has different biological structure that affects healing process. For example, the procedure and time of the regeneration of a tissue varies from an athlete to athlete because of the biological factors.

Functional parameters are the assessment of the physical condition of an injured athlete. After the rehabilitation period, the athlete should perform stretches and execute essential movements without pain. Otherwise, the repaired tissue doesn't satisfy desired mechanical load. If the tissue doesn't heal completely, it can lead to a re-injury (Creighton, Shrier, Shultz, Meeuwisse, & Matheson, 2010). So, insufficient functional recovery delays the healing process.

Physical injury has some serious consequences during healing process. Injured athletes can be deprived of material and nonmaterial support such as losing sponsorship or advertising agreement, reputation and interest showed by sports fan. Economic and moral outcomes lead athletes to suffer from a high level of stress, emotional tension and anxiety (Jaen & Garcia, 2017). When an athlete gets injured, it influences his/her sports activity up to a 4-fold raise in the risk of re-injury (Fueller, Bahr, Dick, & al., 2007). Fear of re-injury inclines the loss of self-confidence and performance of the athlete. To overcome these obstacles, depend on injured athlete's experience, maturity and seriousness of the injury (Jaen & Garcia, 2017). Even if physical status satisfies the conditions, psychological factors influence negatively return to game decision (Tjong, Murnaghan, Nyhof-Young, & Ogilvie-Harris, 2014).

RTP in sports decision is not only affected by multiple criteria but also multiple decision-makers (DMs) like physiotherapists, coaches, athletes. The stakeholders can have heterogeneous perspectives on the timing of RTP. For example, an athlete can have a different viewpoint for RTP decision because of economic and psychological factors such as anxiety for re-injury, low-self-esteem, career and expectations of fans (Shrier, Charland, Mohtadi, & al., 2020). The different perspectives on the decision can cause conflict and miscommunication between athletes and clinicians. This conflict can damage the trust relationship between agents and decrease athletes' therapy adherence (Rodriguez-Osorio & Domingues-Cherit, 2008). To solve this conflict and achieve successful treatment, the athlete should actively participate in the decision-making process (Mazur, 2001). It can be possible by applying SDM approach for RTS decision-making process. SDM allows multiple DMs to express their thoughts and provides a transparency among them. It builds a good communication environment between athletes and physiotherapists to discuss about advantages and disadvantages of the options. Listening and making empathy are crucial for RTS decision-making process which necessitates emotional intelligence and building trust between participants (Stalnikowicz & Brezis, 2020). SDM provides this interactions and help DMs to build a consensus about RTS decision-making.

Depending on obstacles occurred by multi-stakeholders and multi-criteria, RTP in sports decisions are complex and person-based problems that require risk management. This complexity brings out a new question to answer: 'How is the RTP decision made'?

This thesis aims to investigate this question by applying shared decision-making approach within a consideration of decision DMs' physical, social and psychological impacts on the decision and aiding clinicians in making a proper decision on RTP in sport which is matched with other participants' preferences about risk management. The research questions to achieve this goal are addressed below:

Q.1. Which criteria can be used to determine the psychological and sociological states of the athletes, and how can the prioritization of these criteria be modeled?
Q.2. Do the final decisions change according to personal criteria?
Q.3. How to conceptualize and implement shared decision making method in RTP in sport?
Q.4. How helpful are decision aids in involving the athlete in decision-making in RTP in sport?

To assist in finding answers to the questions above, a web-based tool, Return to Play in Sport Decision Aid, has been proposed. The tool implements a multi-criteria decision analysis (MCDA) method by integrating it with SDM approach. The decision aid tool aims to help DMs on RTS decision-making process. To apply SDM in medical practice, the preferences and values of the athletes are need to be determined. This process is performed by the tool which applies AHP technique to get the personal criteria.

In RTS literature, most of the studies are related to physical effects of the injury and ignore psychological impacts of the healing process. After 'Return to Play in Sport Decision Aid' tool is used by athletes and healthcare professionals, we could determine the personal criteria and their influence on decision-making. So, we could increase the satisfaction of the decision-making process by taking personal parameters into account and involving the athletes in the process. Moreover, the gap between healthcare in sport and shared decision making will be reduced. Instead of focusing on just physical factors, we want to model individual aspects of RTP in sport. By considering private criteria for each athlete, we will try to accomplish a person-based decision aid tool and we will discuss other ideas on the topic.

In the following chapters, Chapter two presents medical decision making concepts from past to present and decision aid systems. Chapter three presents Multi-Criteria Decision Analysis methods and previously made some studies. In Chapter four, the details of developed decision aid application and a case study are presented. The experiment results of the study are presented in Chapter five. Finally, Chapter six presents a discussion about application findings and gives concluding remarks.

CHAPTER 2

MEDICAL DECISION MAKING

Decision-making is a crucial part of a human cognitive system. It is one of the complex problems in human nature which consists of rational, heuristic or intuitive alternatives besides economic, scientific and management effects (Yu, Shen, Miao, & et, 2017). During decision process, DMs make selection among possible alternatives by collecting information and evaluating alternative options. Guitouni and Martel defines decision domain in three categories; (1) rational decision which aggregates the alternative assessments and chooses the one providing maximum satisfaction, (2) non-rational decision in which DMs decide based on their experiences, (3) irrational decision which regards personal desire and aversion (Guitouni & Martel, 1998).

This complicated cognitive process depends on DMs' preferences, needs and values, and their continuous interaction with people and the environment. The process can also be affected by the perception of other participants' attitudes (Petukhova, Sharifullaeva, & et, 2019) because decision priorities can vary according to DMs. The human brain of the DMs that can store the limited information determines the capacity for decision-making operation (Ruhe & Wnag, 2007).

Medical decision-making process includes diagnosis or treatment for the patients by interacting with them, based on test results and observations. The decision process can have a recursive structure in some cases. For example; in sport injuries, as long as the healing process continues and conditions of the athlete are changed, decision-making process recurs (Creighton, Shrier, Shultz, Meeuwisse, & Matheson, 2010). It is a complex and dynamic process based on multiple DMs and their interests and pressures (Guindo, Wagner, Baltussen, & al., 2012). Having more than one decision-maker (DM) can cause uncertainty in the agreement on the determination of options and criteria. In addition to uncertainty situations, patient care decision in local healthcare is negatively influenced by some factors like clinical circumstances, ambiguous prognosis, unknown treatment effects, time pressure, the working knowledge base about the problem and irreversible results (Elstein, 1967; Tversky, Sattath, & Slovic, 1988; Croskerry, 2002; Dawson & Arkes, 1987; Dolan, 2008). These factors cause complex and uncontrolled circumstances to occur.

Decision-making process in healthcare is difficult because medical outcomes can be probabilistic and decisions are made in conditions of uncertainty. The outcome of the decision can irreversibly affect the health of patients. So, decisions about healthcare process depend on risks and benefits balance which have serious consequences on patients. In decision making process, healthcare professionals help patients to determine the acceptable risk levels (Creighton, Shrier, Shultz, Meeuwisse, & Matheson, 2010). Patients should be well informed about treatment option before making decision. Otherwise, they are misled about what is important to them and establish preferences in the wrong way. So, patients should figure out their medical situation, the risks and benefits of the possible options, and follow the advice recommended by healthcare professionals. However, many patients do not adhere medical recommendations and show lack of trust and communication with their healthcare professionals because of their biased opinions against suggested medical strategies and treatments (Gorini & Pravettoni, 2011). To increase the quality of medical decisions and prevent previously mentioned problems, researchers investigate two main concepts, how decision is made by healthcare professionals and patients in real-world and how to apply SDM process between stakeholders (Patel, Kaufman, & Arocha, 2002).

Qualitative and quantitative researches in decision-making aim to aid effective decision-making and selecting suitable decision criteria in this process. While quantitative studies focus on SDM process with limited number of factors and outcomes, qualitative analyses examine socio-cultural situation of the process (Lippa, Feufel, Robinson, & Shalin, 2017). In this study, quantitative research method is applied with SDM. The rest of the section will describe different decision-making models between healthcare professionals and patients based on their interactions.

2.1. Traditional Decision Making Models

Traditional decision-making models consist of two approaches, normative and descriptive. The normative model focuses on how DMs should decide. The descriptive approach investigates how DMs actually make decisions (Gorini & Pravettoni, 2011). The normative model aims for patients to choose the best decision option fully and rationally. However, individuals' decisions are often affected by their psychological, emotional, and cognitive situations. In the real-life process, the normative model disregards some factors like the patient's limited cognitive capacity, ambiguity, and risk of the decision. Cognitive strategies help patients to overcome the ignored difficulties derived from ambiguity and limited rationality (Gorini & Pravettoni, 2011). So, instead of a normative approach, decisions are made based on the patient's cognitive ability, preferences, and psychological and emotional situations (Gorini & Pravettoni, 2011).

In conditions where information is insufficient and uncertain, heuristics help patients in the decision-making process. Using heuristics for the process saves time and effort but leads to biases. The heuristic can be useful where a quick decision is needed and the diagnosis blocks the logic to create a proper solution (Gorini & Pravettoni, 2011). However, in some cases, heuristics and biases can lead to wrong diagnosis and improper options. Table 1 shows a list of the most common heuristics and biases in medicine.

2.2. Decision Making Models Between Doctor and Patient

In the healthcare domain, the relationship between patient and physician and the investigation for an ideal physician-patient interaction model are important research topics. Many challenging problems such as the issues of ethics, the legality of physicians' duties, the expectation of patients, and the irreversible results of medical malpractice are affected by these relations There are different patterns for physician-patient interaction in healthcare to overcome those problems. These approaches in the decision process can vary from primarily individual to fully distributed. The role (clinician or patient) who takes the responsibilities for fulfilling the tasks like determining decision points & parameters and making the final decision can change based on these models.

2.2.1. Paternalistic (Physician-Dominated) Decisions

The most common model encountered in medicine is a paternalistic model in which health professionals dominate the treatment decision. It is applied when patients look for urgent care and their capacity does not allow them to assess the situation at that time. The physician recommends the best treatment options for the patient. The applied treatment method and the reason for this action should be explained to the patients and their families by physicians. However, this approach gives a rise to a power imbalance between the patient and the physician. As healthcare professional does not know the patient's perspective on the suggested option, the model causes a conflict between basic anatomy and beneficence (Hope, Savulescu, & Hendrick, 2008). To resolve the power imbalance, patients should play an active role in decision-making process.

2.2.2. Patient-Defined Physician-Made Decisions

Patients identify the decision parameters and physicians match up available treatment options with these parameters. Generally, this model is applied when looking for a treatment for pain and infection. In this model, the patient's ability to determine the symptoms is the key role. The doctor is informed about the patient's needs and medical history. Then the physician addresses these issues with available medical options. For example, when a patient wants to receive sleeping pills, the doctor asks the patient's current condition and previous medications etc.

2.2.3. Patient-Dominated Decisions

In a patient-dominated approach, patients apply self-care treatment and decide if they seek or discontinue care like canceling appointment and delaying treatment (Lippa, Feufel, Robinson, & Shalin, 2017).

2.2.4. Patient-Centered Decisions

Patients play an active role in their medical decision process with the cooperation of physicians. They are empowered to express their needs and involve in the healthcare plan. The power imbalance caused by the physician-dominated approach can be achieved with the patient-centered decision making (PCDM) approach which is based on a SDM model and negotiation between the healthcare provider and patients (Hope, Savulescu, & Hendrick, 2008). As patient care decision is personally identifiable, a patient-centered approach is consistent with the uniqueness of individuals. Some studies prove that patient-centered care promotes better decision results and patient outcomes, enhances patients' satisfaction level (Dolan, 2008) According to Mead and Bower, the patient-centered approach consists of the five basic components (Duggan, Geller, Cooper, & Beach, 2006; Mead N & P., 2002);

- The biopsychosocial perspective,
- Understanding the patients and their rights,
- Sharing power and responsibility between doctor and patient which refers to SDM approach,
- Building a relationship,
- Understanding the healthcare professional as a person.

Table 1: Heuristics and bias in medicine (Gorini & Pravettoni, 2011). This table contains the most common heuristics and biases in medicine.

Aggregate bias	When physicians believe that aggregated data, such as those used to develop clinical practice guidelines, do not apply to individual patients, they are invoking the aggregate fallacy. The fallacy consists in believing that their patients are atypical and this might lead to errors such as prescribing clinical evaluations or exams even if guidelines indicate that they are not required
Anchoring	Anchoring happens when a physician remains anchored to salient features in the patient's initial presentation too early in the diagnostic process without adjusting the outcome when further information are available. This error may be severely compounded by the confirmation bias.
Ascertainment bias	It is an automatic distortion in measuring the true frequency of a specific phenomenon due to the way in which the data are collected
Availability bias	It is a general disposition of the human thought to evaluate things as being more probable, if they easily come to mind. In medicine, recent experiences with clinical problems often provoke availability bias resulting in diagnostic errors.
Base-rate neglect bias	It happens when a physician ignores the real occurrence of a disease, either inflating or reducing its base-rate, distorting the correct Bayesian reasoning
Commission bias	It is the predisposition to action rather than inaction. It is common in overconfident physicians.
Confirmation bias	Confirmation bias is a common bias in medicine that happens when physicians misinterpret symptoms and remember things as they wish they had happened. They may notice and consider only those signs and symptoms consistent with their favored diagnosis and ignore aspects inconsistent with it
Diagnosis momentum bias happens	It when an initial, possible diagnosis becomes definite (even if it is not really the right one) and all the other possibilities are excluded.
Framing effect	The way in which problems are framed strongly influence the way in which physicians evaluate the situation and make their diagnoses.
Fundamental attribution error	It is a typical error occurring with psychiatric patients or marginalized groups and consists in the tendency to be judgmental and blame patients for their illness instead of examining the situational circumstances that might have been responsible.
Gambler's fallacy	The gambler's fallacy is defined as a cognitive error that leads physicians to believe that independent events are related. It happens when physicians consider that the probability that a patient has a particular diagnosis might be influenced by preceding but independent events.
Gender bias	It happens when physicians believe that the gender of the patient determine the probability of a certain diagnosis even if there are no data supporting this hypothesis.
Hindsight bias	Hindsight bias is the tendency to interpret events that have occurred as being more predictable than they were before they took place
Multiple alternatives bias	It occurs when too many options on a differential diagnosis lead to conflict and uncertainty.
Omission bias	It is the tendency toward inaction instead of action. Omission bias is sustained by the idea that events that occur through the natural progression of a disease are more acceptable than those that may be attributed directly to the action of the physician.

2.3. Shared Decision Making

Shared decision-making (SDM) is one of the new approaches to making a decision where at least two participants have a voice on the tasks or the problems. In this technique, the participants work together and share available alternatives to make a decision. Building good communication between participants is the key factor to achieving a SDM process successfully. The model provides interaction between participants, helps patients to state their preferences, and learn different criteria about their treatment process. It assumes that clinicians share medical information with the patients and let them analyze this data to make a preference for treatment alternatives (Ozdemir & Finkelstein, 2018).

SDM approach is used for the health care area which considers patients' preferences and values while deciding on clinical treatment. In medical SDM, participants share information and build a consensus about the treatment method which will be implemented (Charles, Gafni, & Whelan, 1997). This consensus can consist of treatment plans and future tests where the patients' choices and clinical viewpoints are matched based on acceptable risks and benefits. To decide the ideal decision for that kind of complex problem, the benefits and risks of the choices should be weighted and acceptable risk should be defined.

The SDM approach consists of several steps (Makoul & Clayman, 2006);

- Definition of the problem and the options,
- Analysis of the advantages and disadvantages of options,
- Extraction values and preferences of patient,
- Medical recommendations,
- Review of patient’s ability to apply model,
- Control the understanding,
- Making a decision or postponing it.

The SDM approach is the best feasible model in medical practice because of the increased information exchange between multiple DMs. Physicians need patients to get personal preferences and adhere to the treatment, but at the same time patients depends upon the physicians to obtain medical information and expertise (Lippa, Feufel, Robinson, & Shalin, 2017). This cooperation between the patient and the physician shows that SDM is a distributed cognitive process (Engeström, Engeström, & Kerosuo, 2003; Epstein, 2013; Lippa, Feufel, Robinson, & Shalin, 2017).

In SDM approach, a patient and his/her physician determine and assess the alternatives based on the patient’s case and then decide the best treatment option together. By sharing decisions, patients are effectively involved treatment process instead of being passive participants. To involve the patient in the decision-making process, the patient should be aware of the risks and benefits associated with each alternative and express his/her preferences and concern about each treatment option (Gorini & Pravettoni, 2011). The treatment options are evaluated by the integration of the patient's preferences and physician's knowledge.

2.3.1. Advantages of SDM

As the benefits and risks of alternatives are the main factors for decision process, patients become dissatisfied when they uninformed about these elements (Coulter, 2010). Using SDM for decision support raises knowledge of patients about the risky outcomes and provides patients' attendance in the decision-making process by contributing to communication between patient and clinician and helps to match patients' preferences with clinicians' opinions. This improvement in communication achieves trust among the participants and solves conflicts between patients and clinicians. In SDM, patients have a voice in the decision and take an active role in medical decisions. According to the national patient survey conducted by form Care Quality Commission, 48% of inpatient and 30% of primary care patients would have liked more participants on their healthcare decision process (Commission, 2010). When they involve in the medical decision-making process, it increases the quality of the decision and they show reduced symptom distress, illness concern, stress, anxiety, and depression, as well as increased satisfaction with their healthcare professionals, treatment decisions and care received (Gorini & Pravettoni, 2011).

2.3.2. Difficulties in SDM

Although the SDM approach promises hope for medical decision-making, there are some obstacles to overcome like if the patient is willing to be involved in the process, limited information about the complex decision problems, the capacity of the patient, and time pressure for the treatment. In clinical practice, SDM can be difficult and slow (Gravel, Legare, & Graham, 2006). Time, required for SDM for in-depth discussion, is a restriction on urgent cases (Dolan, 2000). Also in some cases, patients feel surprised and unsettled when offered participation in the decision-making process (Politi, Clark, Ombao, Dizon, & Elwyn, 2011). Besides, they can feel abandoned (Quill & Cassel, 1995) and reject taking responsibility for the decision-making process (Say, Murtagh, & Thomson, 2006).

2.3.3. Implementing SDM in RTP

When implementing a SDM process in RTP cases, there are three key roles: a healthcare professional (physician or physiotherapist), an athlete, and a coach. The final decision to RTS can't be isolated from other participants who influence the decision. The mission of the health professionals is to examine and evaluating the health status of the athlete and give recommendations about short-term/long-term health risks such as re-injury and performance detriment (Dijkstra, Pollock, Chakraverty, & Ardern, 2016). The athlete is the final DM of whether he/she returns to play in the sport after injury if he/she has the adequate capacity to make a decision (not in a situation like a concussion). This decision is affected by personal risk management, experience, health information, personal situation, and other factors such as sponsorship deals or media pressure (Dijkstra, Pollock, Chakraverty, & Ardern, 2016). A coach evaluates an athlete's performance after injury treatment based on the athlete's recovery process in rehabilitation, missing workouts, and medical condition (Dijkstra, Pollock, Chakraverty, & Ardern, 2016). As the coach know about the competitions, stage of the season, and match conditions, he/she evaluates the athlete's RTP case in a sport-specific context (Dijkstra, Pollock, Chakraverty, & Ardern, 2016).

2.4. Decision Aid System

A decision aid system helps DMs in the SDM process by providing information about alternatives and options to prevent bias. The interactive communication between patients and the healthcare professional is carried out by the tool during the decision-making process. Decision support technologies do not decide instead of patients or physicians. They are an intermediary that enables the flow of information on personal preferences, options, possible outcomes, and risky situations between DMs. Because of the shortage of time, this information can be bypassed during the consultation process. However, decision aids provide an opportunity to overcome this obstacle.

Decision aids are used when the best treatment option is not clear based on the patient's situation. The tools reveal the information about risks and benefits of the options for the patient. When there are multiple options and the decision is preference-sensitive, based on the patient's reaction to the alternatives (O'Connor, et al., 2007), the decision process can be managed with a tool. The tool guarantees that patients learn the negative and positive effects of treatment options and decide in a controlled manner with approval. Delivery options for decision tools were divided into three categories by Elwyn and coll. (Elwyn, et al., 2011): (1) healthcare professionals use tools for face-to-face interaction; (2) tools are utilized separately from clinical encounters; (3) tools are applied via technology (Gorini & Pravettoni, 2011).

According to a Cochrane review on 55 decision aid trials; "Patients who have used these tools are better informed (mean difference 15.2/100 95% confidence interval 11.7 to 18.7) and less passive in decision making (relative risk 0.6, 0.5, 0.8)." (Elwyn, et al., 2010). Other evidence shows that if patients are well informed and make a decision based on this knowledge, they apply their treatment method more properly (Joosten, DeFuentes-Merillas, de Weert, van der Staak, & de Jong, 2008).

Decision aids, which support SDM process, increase patients' understanding of their care, decrease conflict and encourage them to participate in the decision (Stacey, et al., 2011). However, the implementation of decision aids contains some barriers like being time-consuming, lack of expertise, and healthcare systems that do not support the process (Legare & Witteman, 2013; Friedberg, van Busum, Wexler, Bowen, & Schneider, 2013).

The quality and compliance of decision aid tools are important to reach the proper decision. The International Patient Decision Aids Collaboration (IPDAS) has determined 12 criteria for quality check of decision aid tools in the way of the development process, patient stories, presentation of options, probabilities and conflicts of interests, value clarification, tool delivery, scientific evidence and effectiveness (Gorini & Pravettoni, 2011).

CHAPTER 3

MULTIPLE-CRITERIA DECISION ANALYSIS

Decision problems which consist of discrete decision alternatives and multiple criteria are named multi-criteria decision analysis (MCDA) problems. MCDA has been developed to help DMs make better decisions based on their preferences. Almost all MCDA methods use DMs preferences for recommendation, however, the evaluation and the structuring of them differs by MCDA approaches (Guitouni & Martel, 1998). Structuring of decision cases is the main part of the decision-making process. According to psycho-cognitive studies, structuring process influences preference expressions of DMs (Li & Adams, 1995). They are affected by problem context in terms of political, economic, sociological, cultural, psychological and timing. Regardless of the context, the decision problems can be categorized based on their problematics like description, choice, sorting and ranking (Guitouni & Martel, 1998).

MCDA techniques are suitable to be used for SDM process and the methods that have rational and transparent structure elucidate DMs' preferences and merge them into SDM process (Dolan, Boohaker, Allison, & Imperiale, 2014). According to Thokala et al., MCDA process consists of certain steps (Thokala, Devlin, Marsh, & al., 2016):

- Identifying the problem,
- Determining and modelling criteria,
- Measuring performance,
- Assessing alternatives,
- Weighting criteria,
- Calculating aggregate scores,
- Dealing with uncertainty,
- Reporting the result.

Assessing alternatives is based on selecting a compensation relation between other alternatives. Compensation logic between different evaluations in MCDA methods can be grouped by; compensatory (absolute compensation), non-compensatory (no compensation) and partially compensatory (degree of compensation) (Colson & De Bruyn, 1989). Table 3 shows compensation degrees of the different MCDA methods.

As shown in Figure 1, in terms of theoretical and technical properties MCDA methods can be considered in three parts: input information like criteria, preference elicitation & modelling and aggregation procedure (Guitouni & Martel, 1998). Multi-Criterion Aggregation Procedure (MCAP) consists of preference elicitation modelling and their aggregation process as shown in Figure 1. The aggregation model is important to access the decision result based on preference parameters. There are several MCAP methods related to MCDA approaches (Table 3). To choose the proper aggregation procedure, input information is important. It should be precise and certain as it influences the decision result. The criteria are based on these information and preferences features. Preference elicitation and modelling is a crucial part of the decision-making process. Various approaches are used by different MCDA models which can be grouped by three approaches: the single synthesizing criterion, the outranking synthesizing and the interactive trial-and-error (Roy, 1985). Table 2 describes the most common used MCDA methods and their descriptions.

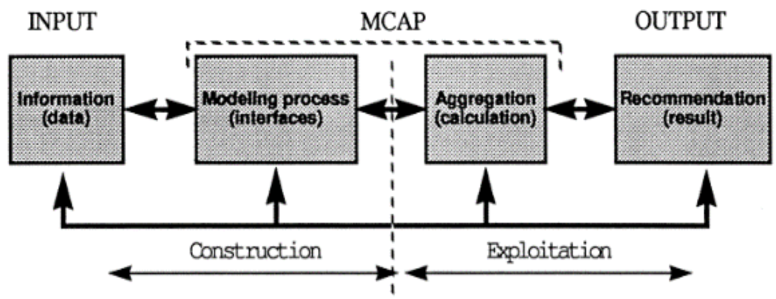

Figure 1: Schematization of a MCDA method (Adapted from (Guitouni & Martel, 1998))

As each decision-making case is unique, the appropriate MCDA method for each should be chosen specifically. Guitouni et al. prepared a guideline on how to choose an appropriate MCDA method for various decision-making problems. Table 3 shows the comparison of the MCDA methods and their structure based on different categories of the mentioned guideline. According to this guideline there are 7 steps to take (Guitouni & Martel, 1998):

1. Identify the stakeholders (DMs)
2. Choose a preference elucidation approach (direct scoring, ranking, pairwise comparison etc.)
3. Determine the decision problematic (choice, description, sorting, ranking)
4. Choose MCAP that fit input information features (cardinal, ordinal, deterministic, non-deterministic etc.)
5. Determine the compensation degree of MCAP method (non, totally or partially)
6. Determine the hypothesis of the method and MCAP treatment methods (eigenvector, sum, thresholds, graph theory etc.)
7. Check if there is decision support system.

This guideline is applied to the study to choose the appropriate MCDA method for RTS decision-making process. DMs are defined as athletes and physiotherapists. Then pairwise comparison was selected for the preference elucidation approach. Athletes determine their values by comparing criteria and then comparing options based on each criterion. Decision problematic is defined as ranking. So, the options are ranked based on the pairwise comparison results. Input values are cardinal and compensation degree of MCAP is identified as partially degree. Eigenvector is chosen as a MCAP method to aggregate the preference values of athletes. As a last step, instead of looking for a decision support system, the decision aid too is developed to calculate the option scores.

Table 2: List of most common MCDA methods (Guitouni & Martel, 1998). This table contains the most common MCDA methods and their descriptions.

MCDA Methods	Description of the Methods
Weighted Sum	The global performance of an alternative is computed as the weighted sum of its evaluations along each criterion.
TOPSIS	The chosen alternative should have a profile which is the nearest to the ideal solution and farthest from the negative-ideal solution.
MAVT (multi-attribute value theory)	Aggregation of the values obtained by assessing partial value functions on each criterion to establish a global value function V. Under some conditions, such V can be obtained in an additive, multiplicative or mixed manner.
SMART (simple multi-attribute rating technique)	Simple way to implement the multi-attribute utility theory by using the weighted linear averages, which give an extremely close approximations to utility functions.
MAUT (multi-attribute utility theory)	Aggregation of the values obtained by assessing partial utility functions on each criterion to establish a global utility function U. Under some conditions, U can be obtained in an additive, multiplicative or distributional manner.
AHP (analytic hierarchy process)	Converting subjective assessments of relative importance into a set of weights. The method applies comparative judgments on elements and measures of relative importance through pairwise comparison which are recombined into an overall rating of options.
ELECTRE I	The procedure seeks to reduce the size of non-dominated set of alternatives. An alternative can be eliminated if it is dominated by other alternatives to a specific degree. The procedure is the first one to seek to aggregate the preferences instead of the performances.
PROMETHEE I	PROMETHEE I is based on the same principles as ELECTRE and introduces six function to describe the DM preferences along each criterion. This procedure provides a partial order of the alternatives using entering and leaving flows.
QUALIFLEX	This procedure uses a successive mutations to provide a ranking of the alternative corroborating with the ordinal information.
Fuzzy conjunctive / disjunctive method	When data are fuzzy, the match between values and standard levels provided by the DM and the evaluations becomes vague and a matter of degree. The degree of matching is computed using the possibility measure and the necessity measure.

Table 3: Comparisons of most common MCDA methods (Guitouni & Martel, 1998). This table contains the most common MCDA methods and their features.

MCDA Methods	Preference Elucidation Mode	Decision Problem	Kind of Information	Compensation Degree	MCAP Treatment
Weighted Sum	Direct rating	Choice	Cardinal	Totally	Algebraic sum
TOPSIS	Direct rating	Choice	Cardinal	Totally	Euclidean distances
MAVT	Tradeoffs	Choice	Cardinal	Partially	Value aggregation (sum or mult)
SMART	Tradeoffs & rating	Choice	Cardinal	Partially	Value aggregation (sum)
MAUT	Tradeoffs & lotteries	Choice	Cardinal	Partially	Utility aggregation (sum or mult)
AHP	Pairwise comparison	Choice & ranking	Cardinal	Partially	Eigenvector method
ELECTRE I	Pairwise comparison	Choice	Mix	Partially	Graph theory (core)
ELECTRE II	Pairwise comparison	Ranking	Mix	Partially	Graph theory (distillation)
PROMETHEE I	Pairwise comparison	Ranking	Mix	Partially	Leaving and entering flows
PROMETHEE II	Pairwise comparison	Ranking	Mix	Partially	Leaving and entering flows
QUALIFLEX	Pairwise comparison	Ranking	Ordinal	Partially	Concordance analysis
Fuzzy conjunctive/ disjunctive method	Direct rating	Choice & sorting	Mix	Non	Possibility and necessity measures

3.1. Criteria Weighting

In MCDA methods, weights represent the importance of the criteria and the point of view of the DMs (Solymosi & Dombi, 1986). In decision making process, different criteria can be evaluated with various importance degree by DMs. However, all of them need to be considered during decision making process regardless of their importance. The given value of each criterion directly influence the outcome. The decision problems where multiple DMs get involved in have extra complexity about different judgements of criteria importance. Because stakeholders own different perspectives, it is difficult to reach consensus among them. According to Arrow's impossibility theorem, the DMs do not have any procedure to assign weights on criteria to satisfy them equally (Arrow, 1963). However, the conflict among DMs can be resolved as the weighting process continues.

There are multiple approaches with different features that guides DMs in weighing the criteria. Ginevicius et al. classified these methods in three (Ginevicius & Podvezko, 2005): subjective, objective and integrated as shown in Table 4. Subjective models depend on personal opinions which can be acquired by questionnaires from DMs. If there is more than one DM, it will take time to reach agreement on the criteria weights in subjective approaches (Odu, 2019). In objective approaches, mathematical models determine the criteria weights, not judgements (Aldian & Taylor, 2005). The integrated methods combine mind and experience of the human beings and criteria data in a mathematical form (Odu, 2019). According to Odu's study, computations at subjective weighting approaches are easier than objective weighting methods which calculates the weight with mathematical model without the DMs' interaction (Odu, 2019).

As getting criteria weights from multiple DMs is a hard process, DMs prefer to give ranks to the criteria (Odu, 2019). So, the weights of the criteria can be obtained from the assigned ranks by stakeholders. This ranking procedure can occur with qualitative or quantitative data. Since qualitative based criteria assessment directly influences the evaluation process, numerical scale from "1 to 9" shown in Table 5 was developed by Saaty in 1977 (Arbel, 1989). This scale is used to transform qualitative data into quantitative values. When the criteria are evaluated qualitatively and need to be converted into quantitative values, bipolar scale for positive and negative indexes can be applied (Asgharpour, 2008). Also, if DMs do not express their real preferences, biased result can occur (Bana e Costa, Corrˆea, De Corte, & Vansnick, 2002).

Table 4: Classification of weighting methods. Adapted from (Odu, 2019).

Subjective Methods	Objective Methods	Integrated Methods
Point allocation	Entropy method	Multiplication synthesis
Direct rating	CRITIC	Additive synthesis
Ranking method	Mean weight	Optimal weighting (sum of squares)
Pairwise comparison	Standard deviation	Optimal weighting (relational coefficient of graduation)
Ratio method	Statistical variance	
Swing method	Ideal point method	
Delphi method		
Nominal group technique		
SMART		

Preference weight of each criterion determines how much it will affect the decision. When the weights are assigned accurately, the decision result satisfies the DMs. However, if DMs feel inadequate or uncomfortable for weighting process, the outcome becomes vague and inaccurate. There are other challenges faced during the assignment of criteria weights:

- To explain the reason of the criteria weights for each stakeholder,
- To ensure every DM participate the process with transparency,
- Scalability of criteria weighting,
- Cognitive burden on stakeholders (Shukla & Auriol, 2013).

Table 5: Pairwise comparison scales. Adapted from (Thomas, 1977)

Intensity of Importance*	**Definition**	**Explanation**
1	Equal importance	Two elements contribute equally to objective
3	Moderate importance	Experience and judgment slightly favor one element over another
5	Strong importance	Experience and judgment strongly favor one element over another
7	Very strong importance	One element is favored very strongly over another
9	Extreme importance	Evidence favoring on element over another is of highest possible order of affirmation

Even scales of 2, 4, 6 and 8 are used to compromise slight differences between two classifications.

DMs are inclined to choose the alternative which is superior to others according to the most important criterion (Sureeyatanapas, 2016) Criteria weighting methods which affect DMs' selection have often steep and non-linear structure (Jia, Fischer, & Dyer, 1998; Fischer & Hawkins, 1993; Tversky & Kahneman, Judgment under uncertainty: heuristics and biases., 1974). Number of DMs, available resources, complexity of the questions and precision tolerance are main elements to select the proper criteria weighting approach (Nemeth, et al., 2019). Nemeth et al. compared common weighting criteria methods in terms of resource use, software requirement, bias and complexity. According to their study, AHP method is categorized as moderate in resource use (budget, timescale and expert number), bias and complexity. They suggest AHP as a feasible solution if multiple DMs weight the criteria importance, however it has some limitations when number of criteria is high. The complexity of the criteria weight approaches connects in reverse with the number and complicatedness of questions (Nemeth, et al., 2019). Increasing complexity of method is associated with low bias. This is contrary to many other situations where complexity is expected to lead to more biased results due to cognitive requirements and burden. (Nemeth, et al., 2019). If cognitive burden of a weighting criteria technique is high for DMs, other methods which pose less cognitive effort are preferred for the process (Shukla & Auriol, 2013).

3.2. AHP (Analytic Hierarchy Process)

AHP is an MCDA method that fits a single synthesizing criterion model. It was proposed by Saaty in 1977. The aim of the AHP analysis is to help DMs in using their preferences for selecting among possible options. In medical decision making identifying patient preferences are crucial for a patient-centered approach. An AHP-based decision support tool can improve medical decisions by aiding elicitation of individual preference and assessment of decision priorities. AHP can help physicians and patients to evaluate their preferences and their influence on medical decision making. For example, emotions can affect the decision making process and cause inconsistent result against DMs' preferences (Shafir & LeBoeuf, 2002). As AHP analysis in decision making process contains intangible factors, it can help eliminate this effect (Dolan, 2008).

AHP analysis divides complex problems into small and easily managed parts and prevents errors that are occurred with complicated cases. It simplifies complex problems and consists of six phrases (Dolan, 2008):

1. Define the decision elements
2. Construct the decision model
3. Decompose the decision into smaller parts making pairwise comparisons
4. Synthesis: How well can alternatives be expected to meet the goal?
5. Sensitivity analysis
6. Make decision or refine the analysis

The first step of AHP is defining the main elements (goal, options and criteria) of the decision problem and collecting the working knowledge base data. The second phase of the AHP constructs a schematic diagram that includes decision elements in a hierarchy. The hierarchical structure of the AHP shows the relations between criteria and the alternatives. These relations display how different selections can affect reaching the goal. The structure of hierarchy helps separating the complex system into

its parts. Because of the dynamic hierarchical structure, the AHP can be adjustable for different size of the problems. Less important criteria can be grouped together as sub-criteria under the title of 'Other Criteria'. Murphy recommends between three and five criteria and sub-criteria to structure a well-managed hierarchy (Murphy, 1993). The hierarchy contains the goal of the decision at the top, the options at the bottom and the decision criteria in between. Figure 2 illustrates the structure of an AHP model.
The third step is dividing problem into smaller parts with pairwise comparison. In the

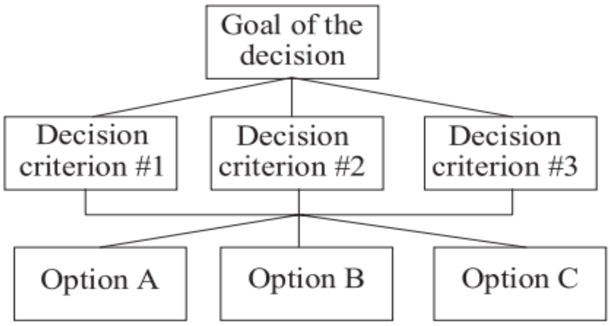

Figure 2: Structure of AHP without sub-criteria (Adapted from (Dolan, 2000)

AHP approach, criteria weights are calculated based on pairwise comparisons and determined in three steps: (1) creating comparison matrix, (2) calculating criteria weight with eigenvector and (3) estimating consistency (Odu, 2019). An example of AHP calculation is given in the Section 4.4. In pairwise comparison, DM compares two elements at a time based on their importance. While the options are compared related to their fulfilment the criteria, the criteria are compared based on their priorities to access the goal (Dolan, 2000). Pairwise comparison is applied in either a 'bottom up' or 'top down' approach. In bottom-up approach, first the preference of alternatives on each criterion are evaluated and then weights of criteria are assigned (Hummel, Bridges, & Ijerman, 2014). However, in top-down approach, criteria weights are assessed first, and then the priorities of the alternatives are determined (Hummel, Bridges, & Ijerman, 2014). If criteria weights depend on fulfillment of the alternatives on criteria, bottom-up approach to apply the pairwise comparisons is recommended (Steele, Carmel, Cross, & Wilcox, 2009). The bottom-up process is preferred because when options are compared first, their strengths and weakness can be realized by participants before criteria comparisons (Dolan, Boohaker, Allison, & Imperiale, 2013).

When applying AHP, the comparison process starts with options or criteria and continues higher or lower level of the hierarchy of the diagram (Fig. 2). Only sub-criteria belongs to same criterion are compared with each other. Every possibility is compared with pair comparison and the required number of comparisons are formulated by

$$c = \frac{n\,(n-1)}{2} \qquad (1)$$

Where c is the number of comparisons: n is the number of criteria.

Pairwise comparison is applied with nine-point scale ranging from equally good to extremely better. Based on the importance of the compared elements, the verbal judgements are transformed to the quantitative ratings (see Table 5). As an alternative option for a nine-point scale, Saaty recommends the scale that starts from 1.1 and ends with 1.9 (Saaty T. L., 2008). While in nine-point scale qualitative transformations increase by 1, in alternative model they increase by 0.1. Since these values are used to calculate the criteria priorities, the differences between comparisons can change slightly in alternative model. Because of ambiguity and vagueness in human judgements (Ren & Sovacool,, 2014), Ren et al. proposed an interval AHP model for multiple stakeholders to weight criteria using interval numbers instead of crisp numbers from 1 to 9 (Ren, et al., 2017). Also, continuous graphic scale offered by some software packages to apply pairwise comparisons provides minor increases in case of preference changing (Hummel, Bridges, & Ijerman, 2014). If there are large number of alternatives, direct rating on intensity levels like excellent, above average, average, below average and poor can be used effectively rather than relative rating with pairwise comparisons (Smith, Cook, & Packer, 2010; Saaty T. L., 2006).

In the study, the classical nine-point scale is used as a quantitative rating for calculating criteria weights and option comparisons. As the pairwise comparisons determine the criteria priorities and option rankings on RTS decision-making process, the verbal judgement values are required to increase by enough range to reveal the difference. So, the crisps numbers from 1 to 9 used in nine-point scale are more convenient to see the difference between comparison results.

The results of pairwise comparisons are entered into the comparison matrix which is used to determine the satisfaction of the decision elements. The importance of the AHP elements is calculated by the eigenvector of the matrix procedure which takes the mean of the result based on their relativeness in the comparison matrix. Then the scores are normalized; all scores in total becomes one.

Analyzing the sensitivity of the comparisons helps to explain the robustness of the decision with consistency check. To determine the consistency among comparisons, comparison matrix and consistency ratio (CR) are used. Consistency ratio is calculated to eliminate comparison errors and check the reliability of the analysis (Dolan, 2008). If consistency ratio is 0.1 or lower, the comparison is accepted as consistent (Dolan, 2000). When the consistency ratio is lower than 0.2, the consistency among pairwise comparisons is considered to be acceptable, however; if it is higher than 0.2, the comparisons are considered to be inconsistent and needed to revise (Saaty T.L., 1980). In case of inconsistency, DMs should change their evaluation about the preferences to meet the consistency standards. Otherwise, decision making process should be delayed until participants improve the working knowledge base about the problem and individual preferences and priorities (Ling, Moskowitz, Wachs, Pearson, & Schroy, 2001).

To calculate the consistency ratio, firstly, weighted sums are computed by multiplying each value by its weights, then adding the results of each row. Second step is dividing vector of weighted sums by corresponding priority value. The next step is averaging the result which gives the estimate value of λ_{max}. If the value of λ_{max} is less than the number of criteria (symbolized by n), calculation error occurs. If not, consistency index can be computed using the required values (Equation 2).

$$CI = \frac{\lambda max - n}{n-1} \qquad (2)$$

To complete the computation of the consistency ratio, random index is required that matches order of the random matrix with index of consistency for random judgements as seen at Table 6 (Odu, 2019). After finding RI from the Saaty's table, consistency ratio is calculated by dividing consistency index by random index (Equation 3).

$$CR = \frac{CI}{RI} \qquad (3)$$

The next step is synthesis. In this process, options are evaluated to determine how they meet the goal. There are two AHP methods, distributive and ideal, to perform this process. The distributive mode is preferred when the goal ranks the options in order by calculating matrix elements with weighted additive approach (Dolan, 2008). When the goal identifies the best option, the ideal approach is used. While the best option for each criteria takes full weight of the criteria, the other options has proportional weight (Dolan, 2008). The same weighted additive approach is applied after weight distribution. Most clinical decision process is applied with ideal approach (Dolan, 2000).

Table 6: Random Index. Adopted from (Saaty T. , 1980)

Order	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.54	1.56	1.57	1.59

Distributive model is recommended, when the performance of alternatives depend on other alternatives but, if the performance of each alternative is compared with a benchmark alternative, then ideal synthesis model is needed to be used (Hummel, Bridges, & Ijerman, 2014). If there is no benchmark alternative, the most preferred alternative can be taken as a benchmark (Hummel, Bridges, & Ijerman, 2014). In distributive mode, the normalization of priorities is calculated to sum up to 1 (Hummel, Bridges, & Ijerman, 2014). A drawback of the distributive mode is that adding or deleting an alternative to the process change the rank order of the prioritized alternatives (Hummel, Bridges, & Ijerman, 2014). To solve this issue, Lootsma suggests using a multiplicative value function rather than additive value function (Lootsma, 1993; Stam & Duarte Silva, 2003).

The fifth step is sensitivity analysis which can determine whether different evaluation values can change the result (Dolan, 2008). When a new alternative is added at the end of the process, the final result could be changed and become invalid. Hyde et al. proposed a distance-based and stochastic uncertainty analysis approach to overcome the limitations of common sensitivity analysis methods like mostly focusing on criteria weights and one parameter variation at a time (Hyde & Maier, 2006). If an alternative is the superior to others regardless of the parameter values like criteria weights and criteria performance values, then the ranking of alternatives is robust and insensitive to data (Hyde & Maier, 2006).

The last step of the analysis is making a decision or refining the analysis. DM can choose the best option revealed by the analysis or combine the analysis result with clinician's perspective (Dolan, 2000). The AHP analysis gives decision results based on information summary, prioritization of needs, elicitation of preferences and values and effective communication among decision stakeholders (Dolan, 2008).

Table 7: Analogy between steps in SDM and steps in AHP procedure. Adapted from (Dolan, 2008)

Steps of SDM	Steps of AHP
Definition of the problem & options available	Create a decision model that contains the decision goal, the options being considered, and the criteria used to determine how well the options are likely to meet the goal
Review of options' pros and cons	Pairwise comparisons regarding how well the options satisfy the criteria
Elicitation of patient values and preferences	Pairwise comparisons to prioritize factors affecting the decision (the decision criteria)
Clinician recommendations	Review results using the clinician's perspective
Review of patient's ability to implement plan	Include feasibility as a decision criterion
Check for clarity and understanding	Detailed review of model results, sensitivity analyses if indicated
Make a decision or defer until later	Use results to inform the decision making process

The AHP has been used for SDM process by improving the decision quality and outcomes and consolidating the relation of doctor-patient (Dolan, 2000). As shown in Table 7, the essential steps of SDM process are similar to the steps of AHP. This analogy supports that AHP can be used to implement SDM in decision support systems.

Although AHP is an effective method for decision making, it can be hard to process information derived from multiple DMs. Determined criteria and alternatives should be clearly explained to the stakeholders to prevent misunderstanding during decision process. The major drawback of AHP is the rapidly increasing number of pairwise comparisons which is directly proportional to the number of criteria. If there are high number of criteria and options, pairwise comparison takes time to perform the analysis and inconsistency issue can show up. Also, a complete aggregation of criteria can be a drawback for AHP, because some information can be lost during trade-off between scores on criteria (Turcksin, Bernardini, & Macharis, 2011).

In this study, AHP is used to RTS decision-making process. It is selected based on Guitouni & Martel's guideline. Also, its' steps are compatible with steps of SDM as shown in Table 7. These two approaches can be implemented together for RTS decision. The drawbacks of the AHP mentioned above are not major concerns for the study. The preference elicitation process is explained to the participants and they are taken by the decision aid tool. As the RTS decision is not an urgent type of decision, time consuming pairwise comparison process is not a problem during the decision. Inconsistency issue is solved by taking the ratio acceptable level, 0.2. The next chapter will explain how to use and evaluate AHP method for RTS decision.

CHAPTER 4

METHODOLOGY

4.1. Design of Study

In this study, a tool has been developed to assist decision-making process in multi-criteria SDM context. This tool was applied to a case study of the decision to RTS after injury. In this context, an AHP based SDM tool was built for the use of sports medicine practitioners and athletes to help them making a better decision on RTS after injury. In this study, physical healing of the athlete is assumed to be examined before the decision-making phase. Therefore, the study focuses on the sociological and psychological impacts of the injury on athletes. The proposed model aims to overcome cognitive problems on RTS decision process and provide an aid for clinicians to utilize for risky decisions which influence not only the health of athletes but also their career and performances.

By using an online tool, athletes can determine their preferences and concerns about RTP decision. Healthcare professionals can evaluate this information with a clinical perspective and interact with athletes to make a shared decision. The tool helps to determine the risky decisions and defines the beneficial and damaging effects of the decision on athletes' careers and social lives.

The main goals of the tool are described as follows:

1. To aid better understanding of sociological and psychological effects of RTS process on injured athletes
2. To improve the decision-making process by providing a better athlete-healthcare professional communication with SDM approach
3. To provide decision support considering athlete’s preferences and values.

The developed decision-making model is based on multi-stakeholders (athlete and healthcare professional), multiple criteria, several options and a decision goal. The goal of the decision model is choosing the best action for the injured athlete. Five major social and psychological criteria that affects RTP decision were derived from the literature to be applied to all sporting injury types (Table 8). Biological and functional factors like patient demographics, lab tests, pain level, joint range of motion, muscular strength and functional tests were not included as criteria because these elements were evaluated before using the tool. The athletes already know their biomedical and physical recovery situation before making a decision about returning to sports. Therefore, the study focuses on the social and the psychological effects of the decision. The definition of the criteria is listed below.

1. **Physical condition and performance:** Athletes must have sufficient muscular strength and an ability to perform sport-specific actions. Besides physical condition, performance of the athletes influence their decision-making process.

2. **Financial concerns:** Financial loss, job security, potential scholarships and contract offers can influence the decision of athlete on RTP.

3. **Stress:** Pressure of competition and external pressure coming from relatives, coaches, teammates, fans and media increase the stress level of athletes.

4. **Self-confidence:** Feeling ready to RTP is based on confidence of athlete which can cause fear and anxiety, associated with higher risk of reinjury.

5. **Fear to get reinjured:** As a psychological reaction, fear of reinjury can negatively affect rehabilitation outcomes and increase the risk of reinjury.

As alternatives of RTS, three options were identified (Table 9) in consultation with two physiotherapists, a professor at Gazi University Athlete Health Center and a specialist in physical therapy and rehabilitation hospital. The definition of the alternatives is listed below.

1. **Return to sport with high or low performance:** After rehabilitation period, if biomedical physical fitness of athletes is approved by physiotherapists, they can return to sports. However, it does not mean athletes perform full performance. It takes long time to achieve to full performance.

2. **Practice with restriction:** Athletes can attend training or team activities with movement restrictions like not jumping or running. Physiotherapists give them permission to do some activities that will not force athletes' injured part of the body. This participation helps to prevent athletes from being disconnected from the sports environment and team spirit.

3. **Not ready to sport:** During the rehabilitation phase after injury, if the athletes do not pass the functional tests and have sufficient muscular strength for sports, physiotherapists tell them they are not ready to RTP in sport.

Table 8: Criteria

Code	Criteria
c_1	Physical condition and performance
c_2	Financial concerns
c_3	Stress
c_4	Self-confidence
c_5	Fear to get reinjured

Table 9: Alternatives

Code	Alternatives
a_1	Return to sport with high or low performance
a_2	Practice with restrictions
a_3	Not ready to return to sport

According to these AHP elements, hierarchical model of the RTS was built as shown at Figure 3. The hierarchy contains the goal of the decision at the top, the options at the bottom and the decision criteria in between.

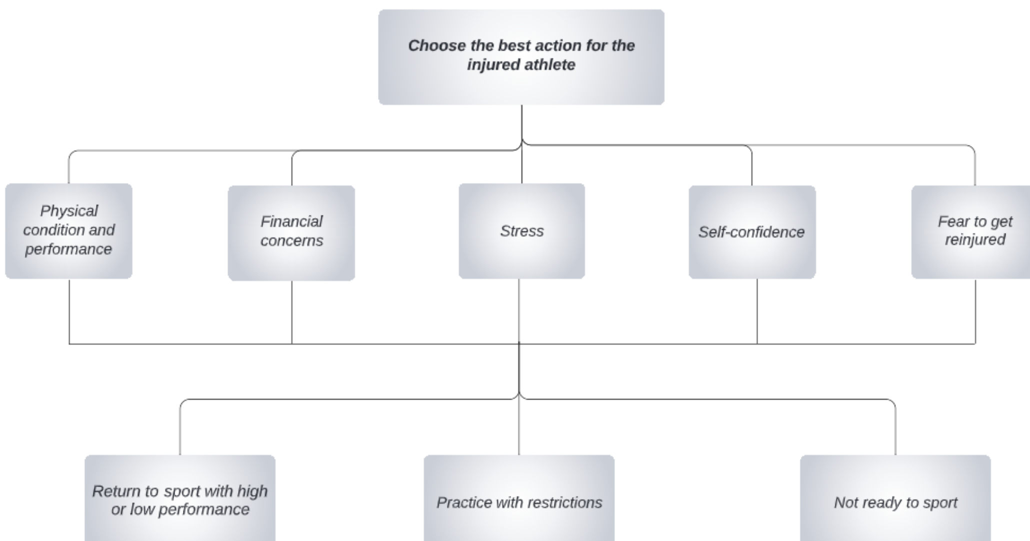

Figure 3: AHP return to sport model.

Developed model aims to analyze the injured athletes' perspective on RTS decision making. To assess the athletes' decision-making strategy based on developed model, two RTS fictive scenarios were created for athletes from various sports categories. The participants will decide among alternatives based on given scenario descriptions and their sport experience. A short description of the sport injury situation including alternatives and healthcare professional's suggested action is given to the participants with the scenario. Each scenario is based on a different sport injury and the study assumed that biomedical and physiological situation of the athlete evaluated before applying the model and the opinion of the healthcare professional is included in the created scenarios. These risky decision scenarios are applicable for every type of sport, either individual or team sports irrespective of the athletes' proficiency level, age and sex.

To create a highly realistic scenarios, the determined injury types are discussed with the physiotherapists. After taking into their professional perspective about the sports injuries, the scenarios were rearranged, and physiotherapists' suggestions were added to the scenarios. Also, some vital details were added to the scenarios in order to reveal the social and psychological effects of the sports injury. The details of the scenarios and physiotherapists' evaluations for the injury types are explained below.

The first scenario was created based on Mayer et. al's Quasi-Naturalistic Scenario study (Mayer. J., 2020). The decision-making scenario in the study was revised and new details were added to the scenario. The injury type of the scenario is a partial tear of the supraspinatus tendon, a short-term injury. According to physiotherapists, this injury type takes 3 weeks to fully recover and then rehabilitation period is required. Athletes can take painkillers to relieve the pain and play at the game, however, it does not have a therapeutic effect. Furthermore, playing sports by suppressing the shoulder pain can increase the physical damage at the shoulder and cause a complete tear of the tendon. In this case, physiotherapists recommend that the injured shoulder should be stabilized using a shoulder sling and the athlete should not play sports until the healing period is over.

Details like type of the game, economic incentives, healthcare professional's recommendation and the extent of the injury were included to the first scenario to discover athletes' social and psychological perspective. The importance of the upcoming game can affect the athletes' decision which is a championship game in the scenario. Endorsement deals were added to the scenario to get athletes to think about financial concerns. Given the information about injury type, its severity and possible risky outcomes determine the athlete's physical condition and performance. Previously determined five criteria in Table 8 were applied to this scenario. Alternatives in the scenario were arranged based on main alternatives in Table 9. First option is withdrawing from the competition and wait for recovery. The second option is not to play in the championship game but to attend the training with a shoulder sling. The last option is participating in the championship game by suppressing the shoulder pain with painkillers. In the first scenario, Alternative A, B and C correspond to a_3, a_2 and a_1 in Table 9, respectively.

The description of the first scenario is presented below:

"Imagine the following situation: You are a professional athlete. For several days, you have had to deal with shoulder pain. During the training session on Thursday, the pain became so bad that you had to abandon the ongoing session. However, your or your team's championship game is scheduled for ten days later and if you do not attend the game, you will lose the endorsement deals. Your coach immediately sends you to see the doctor. After an in-depth examination, the doctor diagnoses a partial tear of the supraspinatus tendon and suggests you not return to play until it recovers fully. Otherwise, the damage at your shoulder can be severe and causes a complete tear of the tendon. You need to inform your coach immediately about whether you will participate in the competition. You must now decide among three alternatives. Which decision do you

communicate to your coach? Alternative A: You decide to withdraw from the competition and wait for recovery. Alternative B: You decide not to play in the championship game but to attend the training with a shoulder sling. Alternative C: You decide to participate in the championship game by suppressing the shoulder pain with painkillers."

The second scenario was created based on a long-term injury; i.e., Achilles tendon rupture. This injury type usually occurs after a trauma and requires a surgery. Physiotherapists stated that full recovery can take up to a year and there is a risk of re-injury. As power loss in operated leg is higher than other leg, long-term rehabilitation period is required for strengthening the leg. If athletes' biomedical and physical condition is approved by physiotherapists, athletes can return to play sport.

Details like timing of sports season, terminated contract, healthcare professional's recommendation, the extent of the injury, long-term rehabilitation period and low performance were included to the second scenario to discover athletes' social and psychological perspective. Previously determined five criteria in Table 8 were applied to this scenario, too. Alternatives in the scenario were arranged based on main alternatives in Table 9. First option is having a lay-off and prepare for the next season. The second option is finding a sports club and play in the current season, despite the low performance and lack of playing time. The last option is finding a sports club and just attend the training. In the first scenario, Alternative A, B and C correspond to a_3, a_1 and a_2 in Table 9, respectively.

The description of the second scenario is presented below:

"Imagine the following situation: You are a professional athlete. During a competitive game, you felt an intense pain with swelling in the back of your lower leg and were not able to complete the game. You immediately see the doctor and he diagnoses Achilles tendon rupture which requires surgery and then long-term rehabilitation for the treatment. During the healing process, your sports club terminates your contract and recruits new athletes. After a six-month rehabilitation period, your biomedical and physical condition were approved and you were allowed to return to sports. However, your post-injury physical performance dramatically reduced, lower than what you and your fans' expected. As the sports season starts soon, you need to decide whether you will play in the season. You must now decide among three alternatives. Alternative A: You decide to have a lay-off and prepare for the next season. Alternative B: You decide to find a sports club and play in the current season, despite the low performance and lack of playing time. Alternative C: You decide to find a sports club and just attend the training."

To reveal the distinct point of view of the athletes for decision making, same medical scenario will use for every participant. The main goal of creating two scenarios is to analyze if athletes can show different approaches for decision making based on the different medical conditions. These two scenarios are implemented on a web based AHP driven SDM aid tool. The following section describes the structure of this tools.

4.2. Program Structure and Description

The proposed web-based Return to Play in Sport Decision aid tool was developed for RTP in sport consultations. It consists of three main structure: frontend, backend and database design. User interfaces were designed as a single-page application using CSS, React and Javascript. Backend was developed based on Onion architecture and Entity Framework using ASP.NET CORE, C# programming language. The advantage of developing web-based application is that is provides accessibility to decision aid tool from anywhere with Internet connection. To save the data that participants enter the system, a database was designed in MSSQL creating data models and ER diagram. Database connection allows analysis and visualization of the result by retrieving and saving athletes' data. As shown in ER diagram in Figure 4, seven table were created with different kind of fields. These tables are connected to each other with primary-foreign key relations. Relation type of the tables like N to N and 1 to N can be seen on the diagram with symbols located at the end of the line connections (Figure 4).

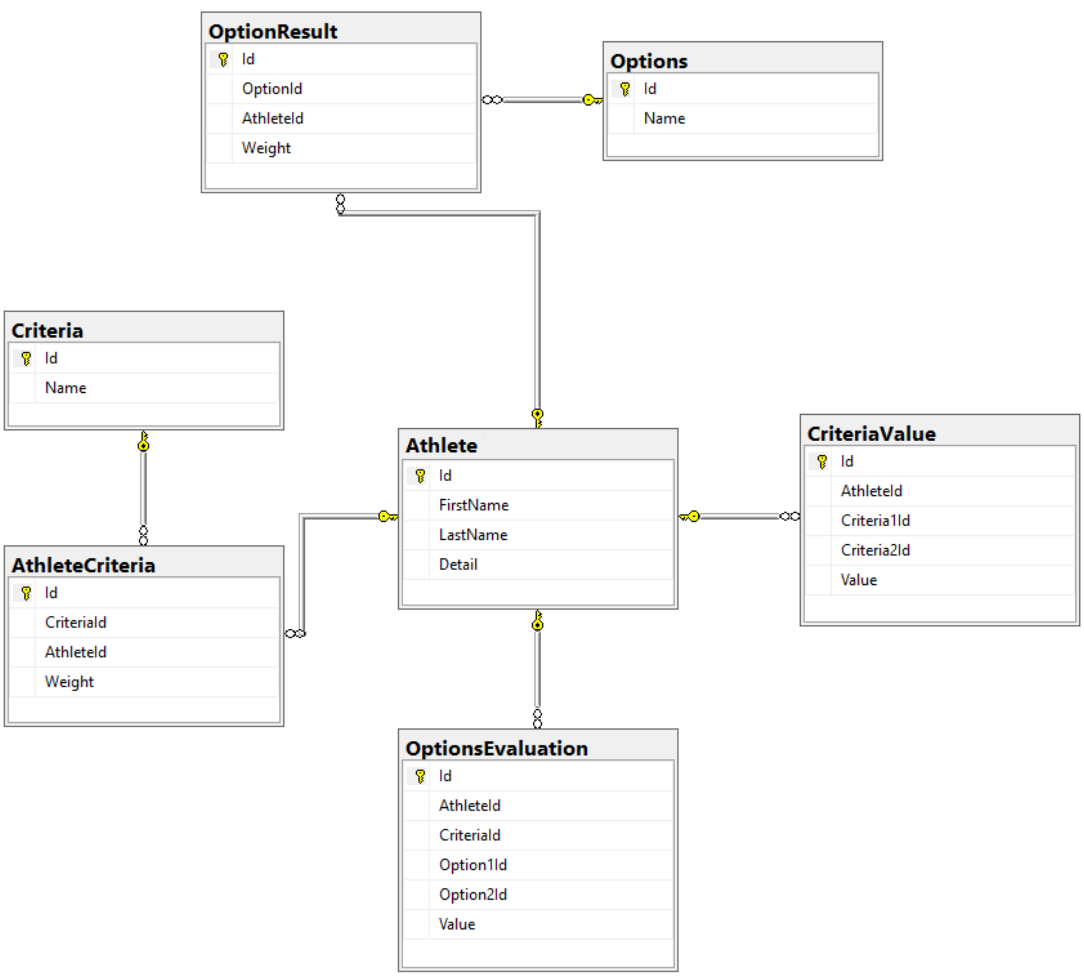

Figure 4: ER diagram of Return to Play in Sport Decision Aid System

Developed decision aid system consists of three main phases. In the first part, the athlete determines the importance of his/her criteria and assess the alternatives by applying pairwise comparison for criteria and options. To identify the athletes' priorities, the study applied the first three steps of the AHP analysis shown in Table 7. This process took about 20 minutes per scenario. In the second phase, the decision aid tool provides an athlete-specific decision by ranking decision alternatives based on athletes' preferences and evaluations. The tool uses AHP and pairwise algorithm to rank the selected criteria and given alternatives. At the last phase, athlete and the healthcare professional discuss the suggested result together and give feedback about the application. This step is done when the athlete and the healthcare professional set an appointment. It aims to improve the communication between athlete and healthcare professional. The detailed flowchart of the decision aid tool is illustrated in Figure 5 and use of the tool is described in the next section (see Section 4.3).

There are certain requirements that need to be met in order to use the tool in practice. Firstly, criteria selection process is a personal task and not all criteria apply to all athletes. Therefore, the tool provides a dynamic choice procedure to athletes to determine their own criteria. Depending on perspective of the participants, criteria can be changed by adding new criteria and removing some of them. Also, since athletes have different background information from each other, the application needs to be user friendly.

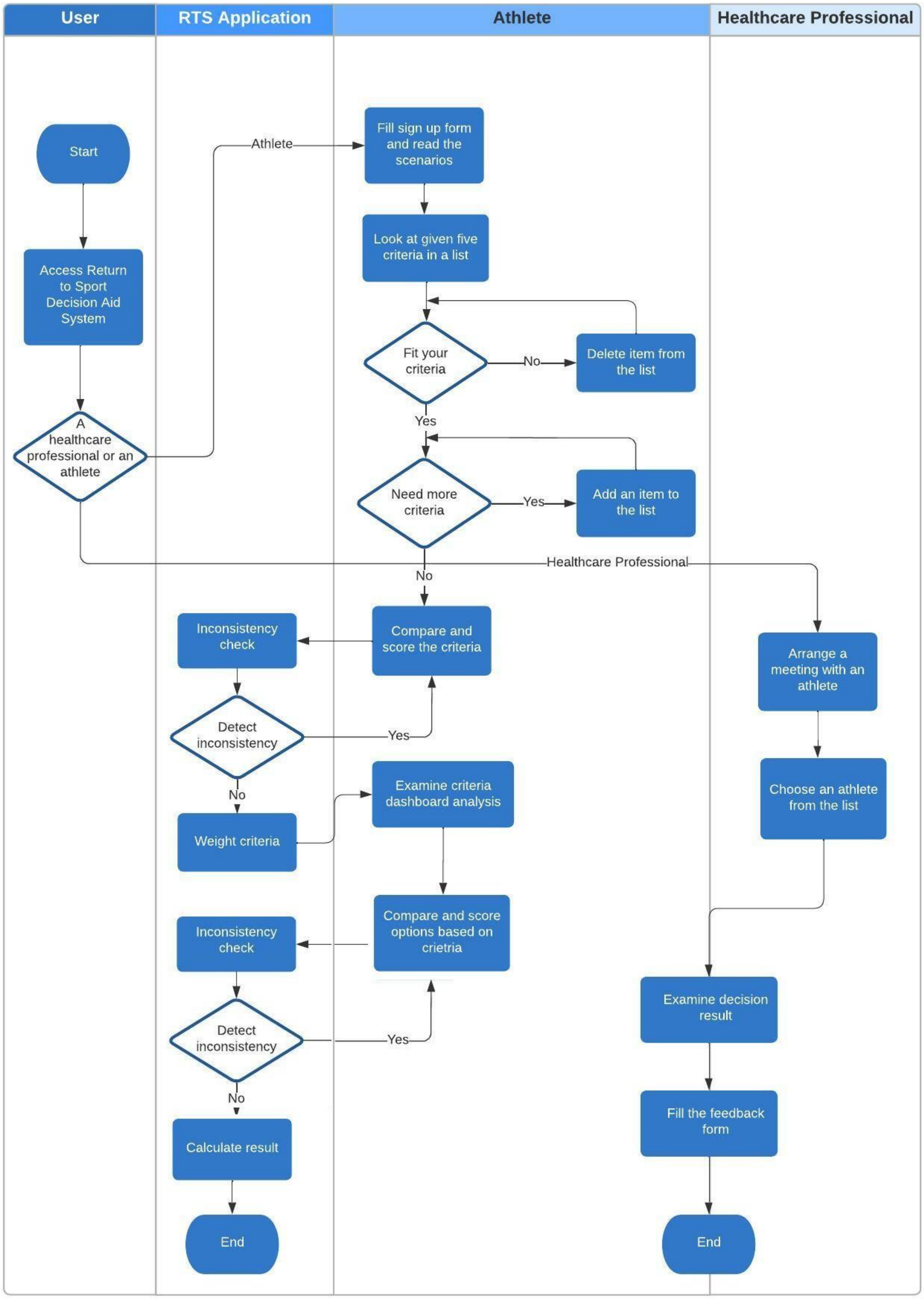

Figure 5: Swimlane flowchart diagram of Return to Play in Sport Decision Aid System

4.3. Data Collection Procedure

People were eligible to join the study if they have/had actively participated in competitions as a licensed athlete in a sports club at any time in their lives regardless of the sports category and proficiency level (amateur or professional). People were excluded if they did not want to attend the study.

Participants were recruited to the study from Gazi University Athlete Health Unit, Faculty of Sports Sciences of universities, gym and fitness centers. After people were informed about the purpose of the study and requested information from the subjects, they were asked whether they want to participate. Interested people were attended to the research as participants. Before starting, participants signed the consent of the volunteer participation form approved by Applied Ethics Research Center (UEAM) at Middle East Technical University (METU).

20 people completed the study; 25% were female and 75% were male. All participants are from different sport categories as shown at Table 10. Also, Figure 6 shows participants' time of playing sports on a yearly basis. 45% of subjects are/were professional athlete and rest of them are/were amateur athlete and 10% are sports instructor. Participants' age is interval from 19 to 65 and average age is 32.35. 15% of subjects have never been injured before. Rest of the participants suffered multiple times from different injuries with a recovery period up to 9 months.

Table 10: Participants' sports categories

Sport Categories	Participants Count
Volleyball	5
Soccer	5
Basketball	2
Handball	2
Judo, Kickbox, Wrestling, Artistic gymnastic, Ice hockey, American football	6

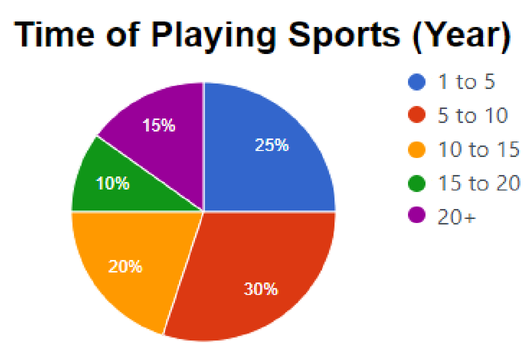

Figure 6: Time of playing sports (Year)

The attendees suffered multiple times from different injury types during their sports lives. These are listed below in order of most common injuries:

- Anterior cruciate ligament rupture,
- Meniscal tear,
- Broken body parts like fingers, wrist etc.
- Ankle sprain,
- Head trauma,
- Shoulder arthritis,

- Herniated disk,
- Nerve entrapment.

The data collection procedure consists of three main structures; collection of information about participants' sport and injury experience, a decision analysis based on two developed scenarios using developed application and an evaluation of AHP-based decision aid tool. Some of the participants did not understand English well enough to complete the study, therefore the application, interview and survey questions are translated to Turkish. All participants completed the decision-making process for both scenarios using developed decision aid tool. Interviews were conducted by study owner and typically took 45 to 60 minutes to complete.

As the first step, participants answered five open-ended questions, shown in Table 11. Athletes' sports category and the duration of playing sports and proficiency level, amateur of professional were gathered using self-report. If the athlete injured before, his/her previous experience based on sports injury were obtained with last three questions of the interview. After the interview, participants used the decision aid tool to determine his/her own decision criteria based on selected scenario and to see the recommended decision result among the alternatives. Participants repeated the same steps using the decision aid tool for the second scenario. As the last step, participants assessed the usefulness of the developed tool in preparing the respondent to communicate with their practitioner at a consultation visit and making a health decision with a questionnaire using a five point scale ranging from 1 (strongly disagree) to 5 (strongly agree) and two open-ended questions (see *Appendix B.1*.). Some of the questions in this survey were created by revising the two different survey questions prepared by AM O'Connor ((Graham, 2010) and (O'Connor, 2002)).

Table 11: Interview questions for the athletes

Questions
What sport did you do and how many years did you play sports?
Did you do the sport as an amateur or professional?
Have you ever suffered a sports injury?
How long did your injury last and were you able to return to sports after this injury?
What factors influenced the decision to quit or return to sports after the injury?

4.4. Case Study

The use of Return to Play in Sport Decision Aid application is demonstrated with a fictional case study using Scenario 1. Given default criteria and alternatives in Table 8 and 9 are preferred for this scenario to decide the best action.

Criteria set C = {c1, c2, c3, c4, c5} and alternative set A = {a1, a2, a3}.

The shared decision aid tool is used by two different user groups, patient and healthcare professional. When the user accesses the system over the internet, he/she chooses one of the available roles (a healthcare professional or an athlete) and clicks the related button. (Fig. 7). Application redirects user to the related process based on the role.

Figure 7: Home page of the application where the user chooses a role.

If the user is an athlete, there are 5 steps as shown in Figure 8 to complete the athlete's process at the decision aid system; signing up form, choosing the criteria, comparing the criteria, analyzing criteria dashboard and evaluating options based on athlete's criteria. The system saves input parameters taken from the athlete to a database system.

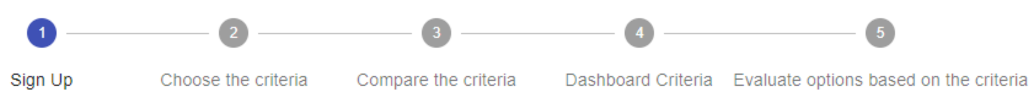

Figure 8: Five steps of an athlete's process

In the first step, the athlete fills the sign up form as shown in Figure 9. He/she enters first name and last name information to the system. Application offers two scenarios to determine the athlete's criteria evaluation strategies. In the case study, the athlete chose Scenario1 and read its description for the next step.

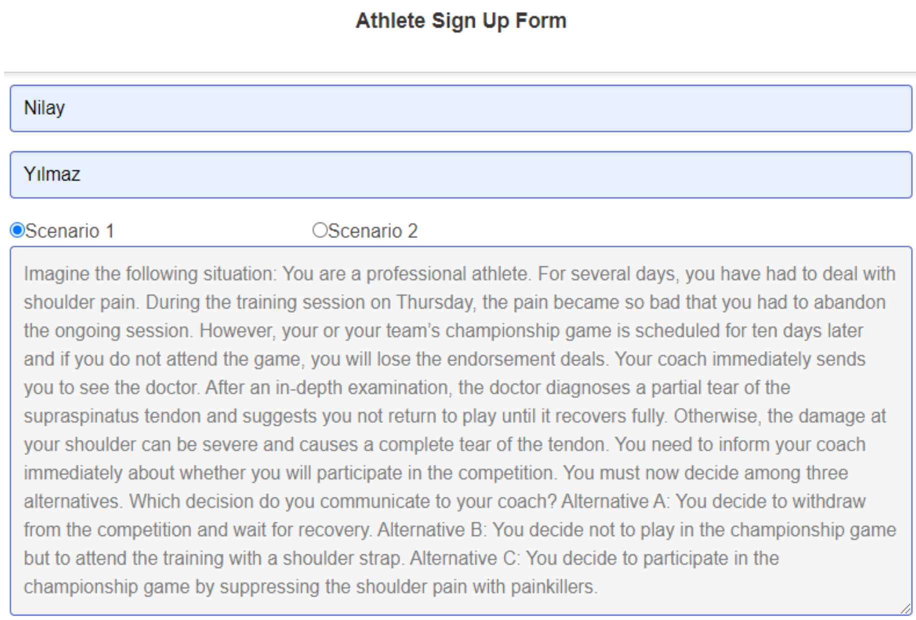

Figure 9: Step 1: Athlete sign up form

The second step aims to help athlete to determine the criteria which affects the decision directly. The system offers five criteria in Table 8 which were determined based on literature review. To get more detail information about these criteria, athlete can move the mouse cursor over the text. The athlete selects the important criteria for his/her condition from the given. If there any criteria which doesn't fit athlete's criteria, athlete deletes criteria and adds a new criterion to the list. In case study, the athlete selected default given five criteria for the decision (Figure 10). Note that the criteria in the list are not ordered by their importance level now. Determination of criteria importance will be done for the next step.

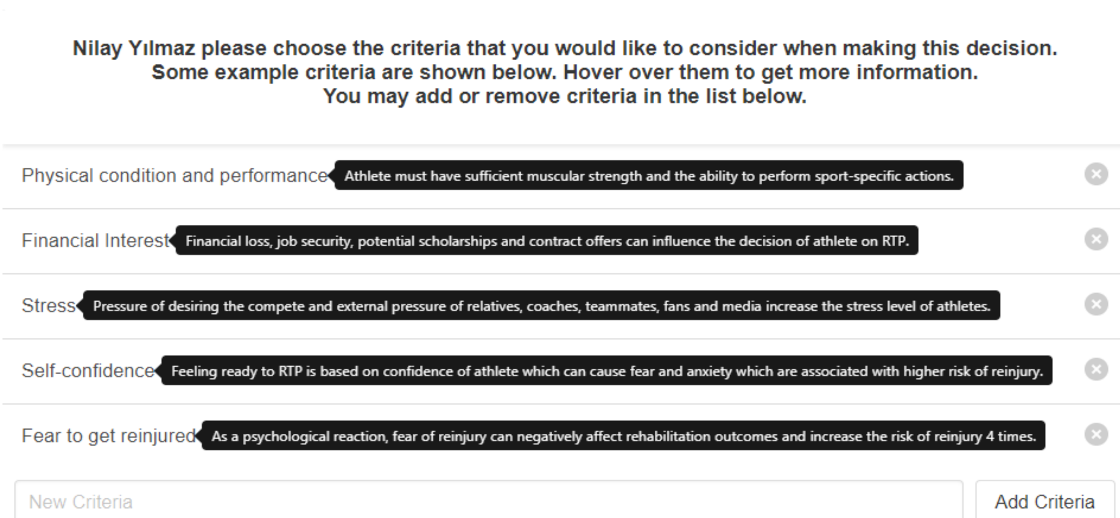

Figure 10: Step 2: Choosing criteria

In the third step, system calculates the priority of the criteria according to athlete's selection. To determine which criteria is more important for the athlete and how much more important it is, athlete compares and scores the selected criteria. For this purpose, pairwise comparison is applied for criteria and athlete selects one verbal assessment from a slider that indicates preferred criteria and its preference degree. As shown in Figure 11, one of the criteria is placed to the right of the slider and the other to the left. Slider consists verbal indicator for both criteria. If the athlete thinks left criteria is important than other criteria, he/she selects a verbal mark on the left side of 'Equal' mark based on an importance degree.

The number of pairwise comparisons depends on the combination number of items. In case study, because athlete selected five criteria, the analysis required ten comparisons, determined by Eq. 1. Considering Scenario1 (Figure 11), athlete indicates that physical condition and performance (c_1) are strongly more important than financial concerns (c_2), but moderately less important than stress (c_3). While self-confidence (c_4) and physical condition and performance (c_1) are equal in criteria importance, fear to get reinjured (c_5) is very strongly more important than physical condition and performance (c_1).

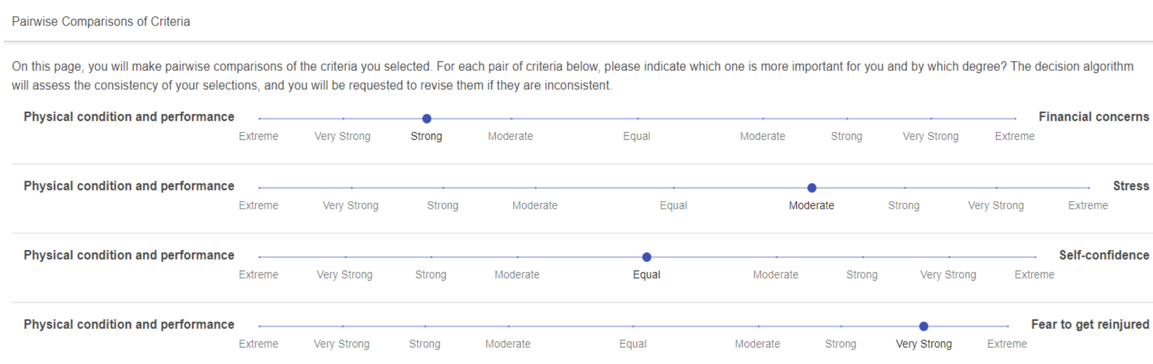

Figure 11: Step 3: Pairwise comparison of the criteria

The results of paired comparisons are used to create a comparison matrix. It represents the results of comparing items. The cells in the matrix indicate the comparison of the row item versus column item. Comparison results are used to fill the elements in upper right triangle of the matrix. The diagonal elements of the matrix are 1 and reciprocal values of upper triangular matrix are entered in the corresponding cells in the lower diagonal. To fill the comparison matrix, intensity of importance values in Table 5 are used to convert athlete's qualitative evaluations to the quantitative scores. All the values of the matrix are positive. If the athlete's subjective judgment indicator is on the left side of 'Equal' mark, translated score value is entered directly to the matrix. However, if the selected indicator is on the right side of the 'Equal' mark, reciprocal value of the converted score is used to fill the comparison matrix.

Comparison matrix is required to calculate the criteria weights, also called priority values. For this purpose, the normalized Eigen vector of the matrix is computed. To normalize the values, elements in each column in comparison matrix are summed and each element is divided by the sum of its column. To calculate the weights, normalized elements in each row are summed and divided by the number of elements. Because the matrix is normalized, the sum of the vector is 1. This vector presents relative weights among the criteria.

Table 12: Pairwise comparison matrix (left) and normalized matrix with weights (right) for the criteria

	c_1	c_2	c_3	c_4	c_5
c_1	1	5	1/3	1	1/7
c_2	1/5	1	1/5	1/3	1/9
c_3	3	5	1	3	1/5
c_4	1	3	1/3	1	1/7
c_5	7	9	5	7	1
Sum	12.2	23	6.86	12.3	1.59

	c_1	c_2	c_3	c_4	c_5	Weights
c_1	0.0819	0.2173	0.0485	0.0813	0.0898	0.1037
c_2	0.0163	0.0434	0.0291	0.0271	0.0698	0.0371
c_3	0.2459	0.2173	0.1457	0.2439	0.1257	0.1957
c_4	0.0819	0.1304	0.0485	0.0813	0.0898	0.0863
c_5	0.5737	0.3913	0.7288	0.5691	0.6289	0.5783

First matrix of Table 12 represents the case study’s pairwise comparison matrix for the criteria. The cells are filled with athlete’s comparison values. Summation of the first column is 12.2 defined by Eq. (4), and the remaining four columns’ total are 23, 6.86, 12.3 and 1.59. Second matrix of Table 11 shows the normalized matrix of criteria comparisons and weights. Normalized value of two cells of the first row are computed by Eq. (5). Using the normalized elements, priority vector of c_1 is calculated by Eq. (6). When the same process is applied for the other criteria, priority vector (weights) is computed. The criteria weights of the case study are 0.1037, 0.0371, 0.1957, 0.0863 and 0.5783.

$$1 + 1/5 + 3 + 1 + 7 = 12.2 \qquad (4)$$

$$1/12.2 = 0.0819 \qquad 5/23 = 0.2173 \qquad (5)$$

$$\frac{\frac{1}{12.2} + \frac{5}{23} + \frac{1/3}{6.86} + \frac{1}{12.3} + \frac{1/7}{1.59}}{5} = 0.1037 \qquad (6)$$

After finding the criteria weights, system checks the consistency for the comparisons. An example can be helpful to explain the consistency condition for pairwise comparisons. As shown in Figure 12, a participant compares three criteria (c_1, c_2, c_3) with number scale. First he/she selects that c_1 is strongly more important than c_2. Next, c_3 is chosen moderately more important than c_1. According to the transitive feature of the logic, for the last comparison, c_3 must be more important than c_2. However, in the example c_2 is selected as very strongly more important than c_3. Therefore, comparisons in Figure 12 are inconsistent. On the contrary, if c_3 is chosen as more important than c_2, scores of the evaluations will be used to calculate the weights.

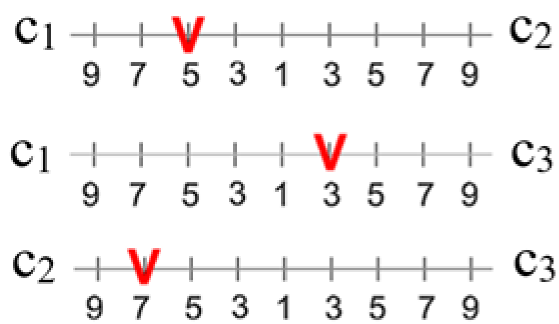

Figure 12: Consistency example of pairwise comparisons

In our case study, if the system detects inconsistency among criteria scores, it warns the user to compare the criteria again. When the comparisons pass the consistency check, system saves the calculated criteria weights for the next steps. To estimate the consistency of the comparisons, firstly sum of each row (weighted sum) at the normalized matrix is calculated and the total is divided by the related weight. For example, first row's weighted sum value (WS) 5.0028 is determined by Eq. (7.). To calculate the value of λ_{max}, WS are summed, and total is divided by the number of criteria. In case study, λ_{max} value is calculated as 5.2789 (Eq. 8.) and consistency index is computed as 0.0697 (Eq. 9.). As the number of criteria in the case study is five, random index becomes 1.12 (Table 6). To compute the consistency ratio, consistency index is divided by random index. For this case study, consistency ratio of criteria comparisons is 0.0622 (Eq. 10.). As the ratio value is lower than 0.2, system accepts the criteria evaluation as consistent. Athlete's criteria evaluation passes to the consistency check. Therefore, there is no need to revise the criteria assessment.

$$WS = \frac{(0.0819 + 0.2173 + 0.0485 + 0.0813 + 0.0898)}{0.1037} = 5.0028 \quad (7)$$

$$\lambda max = (5.0028 + 5.1151 + 5.4558 + 5.2029 + 5.5747) / 5 = 5.2789 \quad (8)$$

$$CI = \frac{(5.2789 - 5)}{4} = 0.0697 \qquad (9)$$

$$CR = 0.0697/1.12 = 0.0622 \qquad (10)$$

At the fourth step, the system shows analysis results which list athlete's criteria based on their importance score. The step aims to inform the athlete about priority of the criteria. The importance percentage of the criteria are shown in the pie chart. Criteria in the list are ranked by their priority value. Athlete examines the criteria analysis result and grasps the importance of the criteria for herself/himself.

The list in the Figure 13 shows ranked criteria of the athlete in the case study. Fear to get reinjured is the most important criterion for the athlete with 58 percent weight. The second important criteria are stress with 20 percent weight. The importance of other criteria is similar. The weight of Physical condition and performance is 10%, Self-confidence is 9%, and Financial concerns is 4%. The ranking of the criteria for the athlete is determined with priority value. Besides ranking, ratio scale of importance is defined by dividing priority values of criteria with each other. For example, fear to get reinjured is 2.9 times important than stress factor, computed by Eq. (11). Since Fear to get reinjured is by far the most important criterion, it will significantly affect RTS decision with alternative evaluations.

$$58/20 = 2.9 \qquad (11)$$

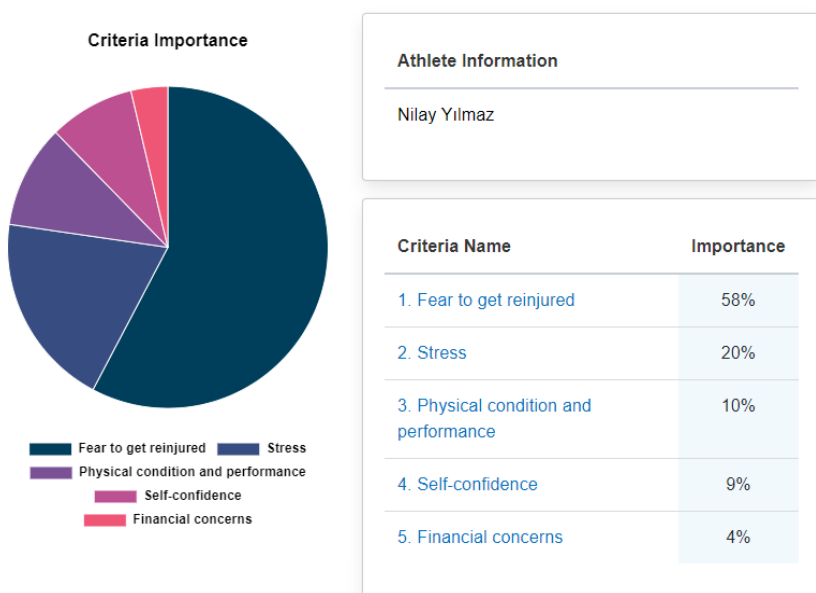

Figure 13: Step 4: Criteria dashboard: priority results of the criteria

At the last step, considering Scenario1, athlete assesses the given three alternatives; Return to sport with high or low performance, Practice with restrictions and Not ready to sport. These alternatives in Table 9 were defined based on the consultation with physiotherapists. “This process determines which alternative is preferable and how much more preferable it is based on athlete’s criteria. Pairwise comparison is applied for the alternative evaluations. As shown in Figure 14, athlete selects one value from a slider for each comparison to score the options regarding the given criteria.

Paired comparison of the alternatives has the same process with criteria comparison. The assessment of the options are entered into the comparison matrix. However, this time elements are compared respect to each criterion. Therefore, there are as many paired comparison matrices as the number of criteria. In case study, because alternatives are compared with each other based on five criteria, there are five paired comparison matrices. Table 13 shows two of these matrices respect to physical condition and performance and stress criteria.

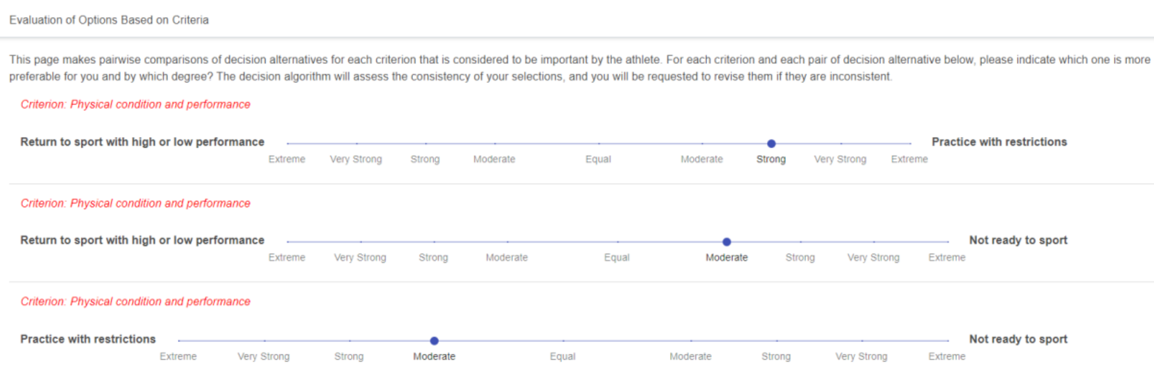

Figure14: Step 5: Evaluations of the options based on the athlete’s criteria

According to Figure 14, when considering physical condition and performance, athlete strongly prefers *Practice with restrictions* option against to *Return to sport with high or low performance*. But respect to the same criteria, *Return to sport with high or low performance* is moderately more preferable than *Not ready to sport*. For the last comparison of the criterion, athlete preferred moderately *Practice with restrictions* against *Not ready to sport*. Quantitative values of these evaluations are written in the first comparison matrix at the Table 13. To calculate the weight of each alternative regarding to each criterion, comparison matrices are converted into the normalized matrices and weights are calculated as the same as in Step 3. After weights of five comparison matrices are computed, system controls inconsistency among option scores. The process is the same as mentioned above in Step 3. If the consistency ratio for each comparison matrix is higher than 0.2, the system asks the user to compare the options again.

Table 13: Paired comparison matrices with respect to physical condition and performance and stress.

	a_1	a_2	a_3	Weights
a_1	1	1/5	1/3	0.1061
a_2	5	1	3	0.6330
a_3	3	1/3	1	0.2604

Criterion: Physical condition and performance

	a_1	a_2	a_3	Weights
a_1	1	1/5	1/7	0.0737
a_2	5	1	1/3	0.2828
a_3	7	3	1	0.6433

Criterion: Stress

If inconsistency is not detected, the result of comparison matrices is combined in a new matrix as shown in Table 14. The result matrix consists of weights of alternatives based on the criteria. The numbers in parentheses next to the criteria indicate their calculated priority values. The number in the columns shows the relative values of the three alternatives meet the five criteria. To calculate the overall composite weight of each option, weight element in each row is multiplied by priority value of the criterion of the same column. For example, the overall score of a_1 (Return to sport with high or low performance) is 0.1517, calculated by Eq. (12.). Scores of other alternatives are 0.2509 and 0.5973.

Table 14: The composite weights of alternatives after pairwise comparison process.

	c_1 (0.1037)	c_2 (0.0371)	c_3 (0.1957)	c_4 (0.0863)	c_5 (0.5783)	Score
a_1	0.1061	0.8181	0.0737	0.6333	0.0714	**0,1517**
a_2	0.6333	0.0909	0.2828	0.2604	0.1804	**0,2509**
a_3	0.2604	0.0909	0.6433	0.1061	0.7481	**0,5973**

$$a1 = (0.1061 * 0.1037) + (0.8181 * 0.0371) + (0.0737 * 0.1957) + (0.6333 * 0.0863) + (0.0714 * 0.5783) = 0.1517 \quad (12)$$

After athlete selects the priority of criteria and evaluates the alternatives, system calculates the overall score for the decision options. The process of the athlete is completed after this step. If a healthcare professional enters the system, related button from homepage of the application (Figure 7) is clicked. This part is organized considering SDM method. Therefore, before starting the process, a healthcare professional sets an appointment with his/her patient whose health the clinician wants to evaluate. During this meeting they apply the defined three steps together. These are choosing an athlete from the list, analyzing the dashboard result, and filling the feedback form (Figure 15).

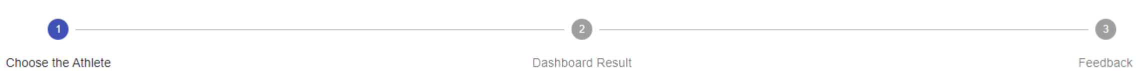

Figure 15: Steps of healthcare professional's process

At the first step of the appointment, healthcare professional starts the process by choosing the athlete information from the list which he/she wants to evaluate the decision status (Figure 16). For the case study, healthcare professional selects the athlete's name and the related scenario from the webpage. Since athlete selected Scenario 1 for the case study, healthcare professional chooses the same scenario and review the case and alternatives. This step aims to inform healthcare professional about the fictional situation of the athlete and let DMs debate the decision consider the selected scenario.

In the next step, the system displays the decision support result in a dashboard. Dashboard consists of athlete's information; suggested decision result and the score lists of ranked alternatives and criteria. The options are ranked based on the criteria weights. The healthcare professional analyzes the result and identifies factors which affect the decision outcome. System displays the suggested alternative and then, athlete and heath care professional discuss about the result. This step aims to improve the communication between healthcare professional and athlete. Healthcare professional learns the athlete's concern by examining the ranked criteria list. The suggested decision option also explains the athlete's position in decision making for the case. After information flow is double-sided, they make the final decision together in accordance with SDM.

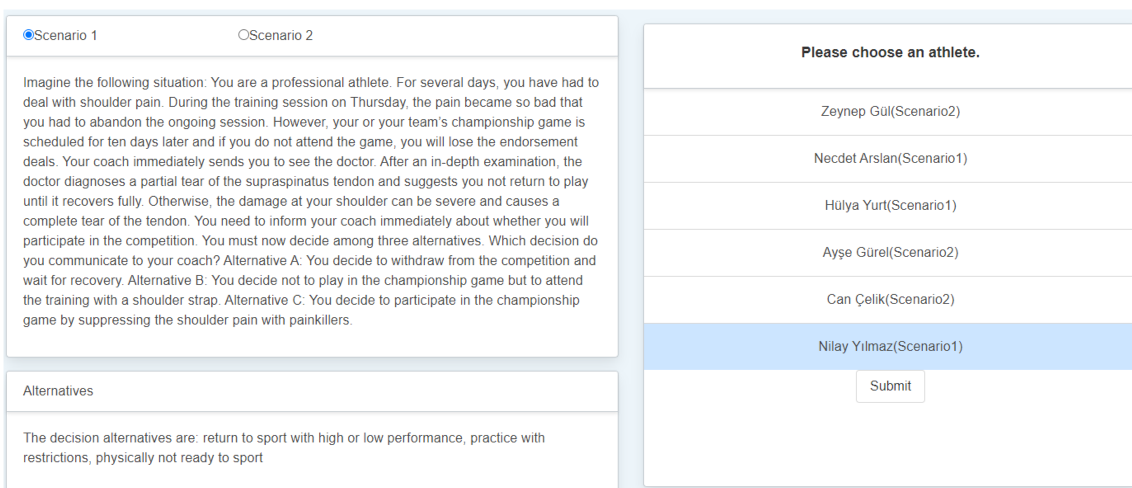

Figure 16: Step 1: Choosing the athlete

Figure 17 shows the final ranking of the case study that represents the decision result and effective factors for the athlete. Not ready to sport option is the best alternative with 60%, followed by Practice with restriction as the second option with 25% and the worst alternative is Return to sport with high or low performance with 15%. After calculating ratio scale, Not ready to sport option is 2.4 times more preferable than Practice with restriction option and 4 times more suitable than Return to sport with high or low performance option. Figure 17 shows the final ranking of the case study that represents the decision result and effective factors for the athlete. Not ready to sport option is the best alternative with 60%, followed by Practice with restriction as the second option with

25% and the worst alternative is Return to sport with restriction as the second option with 25% and the worst alternative is Return to sport with high or low performance with 15%. After calculating ratio scale, Not ready to sport option is 2.4 times more preferable than Practice with restriction option and 4 times more suitable than Return to sport with high or low performance option. The decision aid system by far recommends athlete to Not ready to sport option. Since the scores of alternatives are computed based on the athlete's priority of criteria, Fear of get reinjured criteria with the highest importance score determines the final decision as Not ready to sport. Some criteria do not directly influence the outcome because of low importance value, but they are important for the athlete. Therefore, they still are considered for alternative ranking.

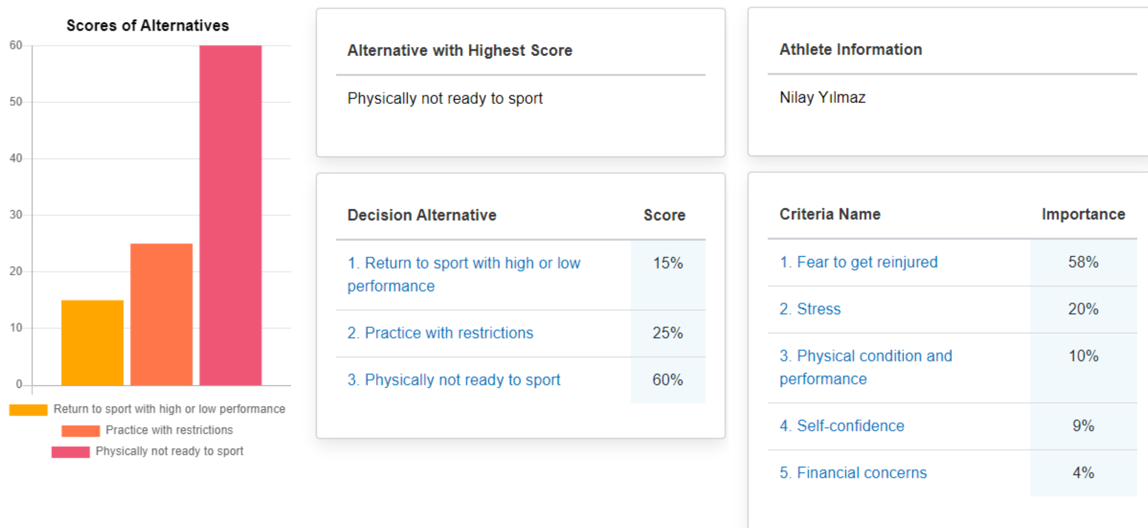

Figure 17: Step 2: Decision dashboard

The last step aims to evaluate the decision aid tool. After result of decision aid tool is displayed, athletes can attend to the surveys and give feedback about the tool. The survey was prepared on the Google Forms platform and embedded to the decision aid application. When the RTS decision result is ready, the system displays the survey questions. The participants join the feedback questionnaires and answer the questions. If users attend the survey once, they do not need to answer the questions again. Note that since healthcare professional could not attend the study because of Covid-19 pandemic, only athletes fill the feedback form.

To evaluate of the decision aid tool, two evaluation measures from Patient Decision Aids Research Group in the Ottawa Hospital Research Institute is used. Acceptability and Preparation for Decision Making Scale are two measurement tools which are applied during the development part of the decision aid tool ((Graham, 2010) and (O'Connor, 2002)). Some questions of these questionnaires were revised and integrated into the system to evaluate the effectiveness of the decision aid tool from athletes' perspective. The athlete's questionnaire consists of 10 multiple choice questions and 2 long answer questions (see *Appendix B.1.*).

CHAPTER 5

EXPERIMENT RESULTS

5.1. Results

After post injury, 45% of the participant athletes joined rehabilitation period. However, not all of them can return to sports. Poor performance, loss of strength and fear of re-injury are the common effects emerged after injury. %20 of the participants have been taking physical therapy during the experiment. One of the participants could not play for a season and waited for full recovery. However, when he returned to play sports, after a while he had to quit playing volleyball because of chronic back pain emerged after injury. The other participant did not get the physical rehabilitation after injury and then could not return to preinjury performance. Therefore, he had to quit playing volleyball too.

5.1.1 Scenario 1

Besides the given five default criteria, participants added four different criteria for the Scenario 1. These are team support, recovery time, career life and success status and effort. The criteria priority weights based on participants are summarized in Table 16. Overall, for Scenario 1, fear to get reinjured was given the highest priority weight (mean weight 45%), followed by physical condition and performance (mean weight 33%), financial concerns (mean weight 21%), stress (mean weight 13%) and self-confidence (mean weight 7%). Other criteria were selected less than 5 times. Therefore, their mean values were not considered for criteria ranking process. Distribution of criteria data can be seen at boxplot graph in Figure 18. Other detail information like sample size, mean and median values are shown at Table 15.

Criteria priorities of Senario1 were evaluated based on professional level of athletes (professional and non-professional) and sport categories (individual or team sports). In the study, there are 9 professional and 11 non-professional athletes. Also, 4 of 20 participants have been playing/played individual sports and rest of them, 16, have been playing/played team sports. The comparison results of criteria priorities are shown at Figure 19 and 20.

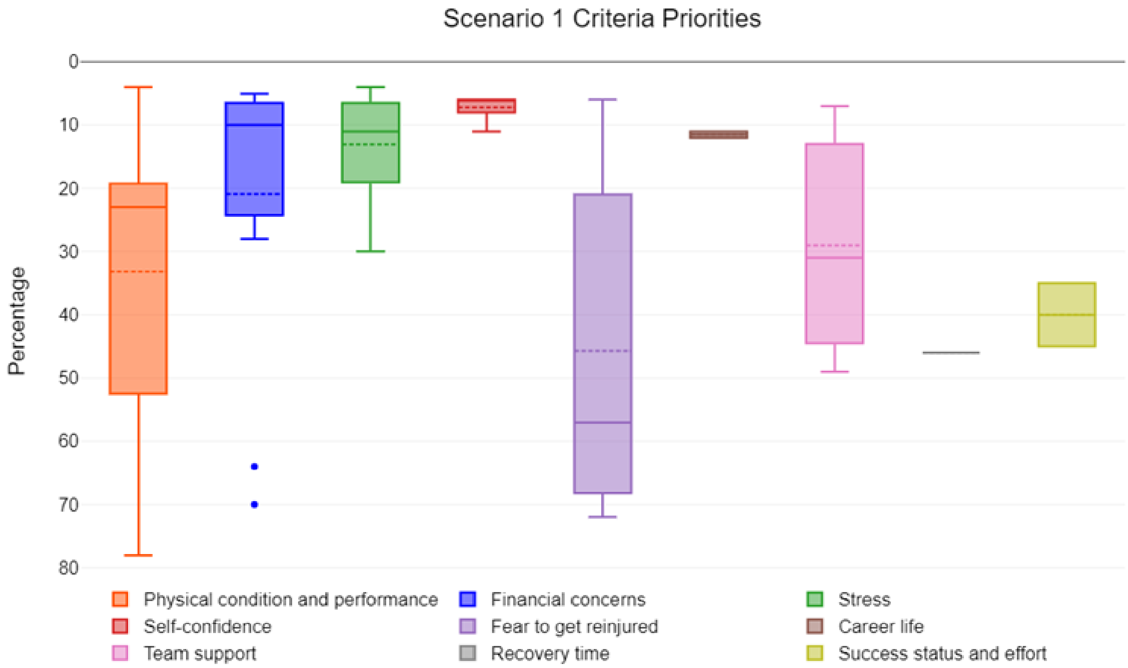

Figure 18: Scenario 1 criteria priorities boxplot graphs

Table 15: Scenario 1 criteria value analysis.

Subjects	**Criteria***								
	c1	**c2**	**c3**	**c4**	**c5**	**c6**	**c7**	**c8**	**c9**
Sample Size (n)	17	11	12	5	17	2	3	1	2
Minimum	4	5	4	6	6	11	7	46	35
Q1	20	7	6.5	6	21	11	19	46	35
Median	23	10	11	6	57	11.5	31	46	40
Q3	47	20.5	19	7	68	12	40	46	45
Maximum	78	70	30	11	72	12	49	46	45
Mean	33.17	20.9	13.08	7.2	45.7	11.5	29	46	40
Outliers		64.7		11					

*c1 = Physical condition and performance, c2 = Financial concerns, c3 = Stress, c4 = Self-confidence, c5 = Fear to get reinjured, c6 = Career life, c7 = Team support, c8 =Recovery time, c9 =Success status and effort.

Table 16: Criteria importance values of participants for Scenario 1.

Subjects	**Criteria***								
	c1	**c2**	**c3**	**c4**	**c5**	**c6**	**c7**	**c8**	**c9**
S1	23%	6%	-	-	60%	12%	-	-	-
S2	-	64%	19%	11%	6%	-	-	-	-
S3	47%	-	-	-	47%	-	7%	-	-
S4	4%	12%	4%	6%	28%	-	-	46%	-
S5	29%	-	14%	-	57%	-	-	-	-
S6	20%	8%	4%	-	68%	-	-	-	-
S7	21%	10%	-	-	69%	-	-	-	-
S8	23%	-	7%	-	70%	-	-	-	-
S9	17%	13%	-	6%	33%	-	31%	-	-
S10	69%	-	10%	-	21%	-	-	-	-
S11	23%	70%	-	7%	-	-	-	-	-
S12	29%	5%	12%	-	19%	-	-	-	35%
S13	69%	-	10%	-	21%	-	-	-	-
S14	78%	-	-	-	11%	11%	-	-	-
S15	24%	-	6%	-	70%	-	-	-	-
S16	-	-	-	6%	-	-	49%	-	45%
S17	9%	-	30%	-	61%	-	-	-	-
S18	72%	8%	19%	-	-	-	-	-	-
S19	-	6%	22%	-	72%	-	-	-	-
S20	7%	28%	-	-	64%	-	-	-	-

*c1 = Physical condition and performance, c2 = Financial concerns, c3 = Stress, c4 = Self-confidence, c5 = Fear to get reinjured, c6 = Career life, c7 = Team support, c8 =Recovery time, c9 =Success status and effort.

The comparisons of criteria priorities were calculated based on the average of given default five criteria. According to the comparison at Figure 19, for Scenario1, non-professional athletes prioritize fear to get reinjured, physical condition and performance and stress more than professionals. However, professionals care more about financial concerns than non-professionals. According to other comparison between team and individual sport players for Scenario 1, shown at Figure 20, individual sport players prioritize financial concerns much more than team sport players. Also, self-confidence is more important criteria for individual sport players. However, team sport players care much more about fear to get reinjured than individual sport players. Also, physical condition and performance is more important for team sport players.

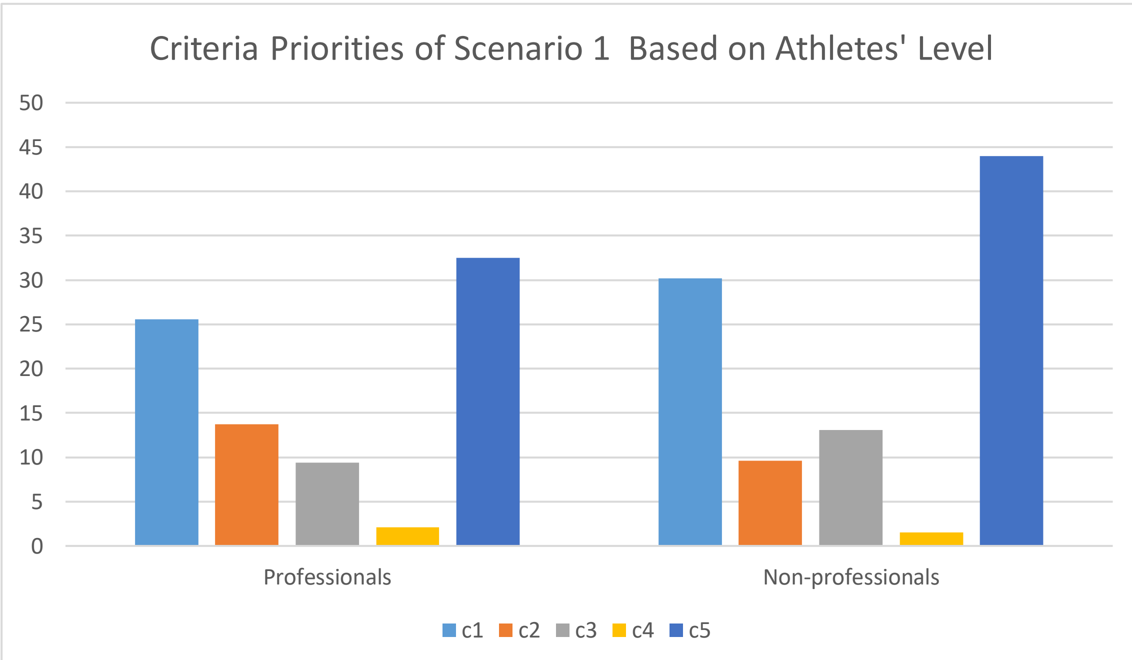

Figure 19: Comparison of criteria priorities of Scenario1 based on athletes' professional level

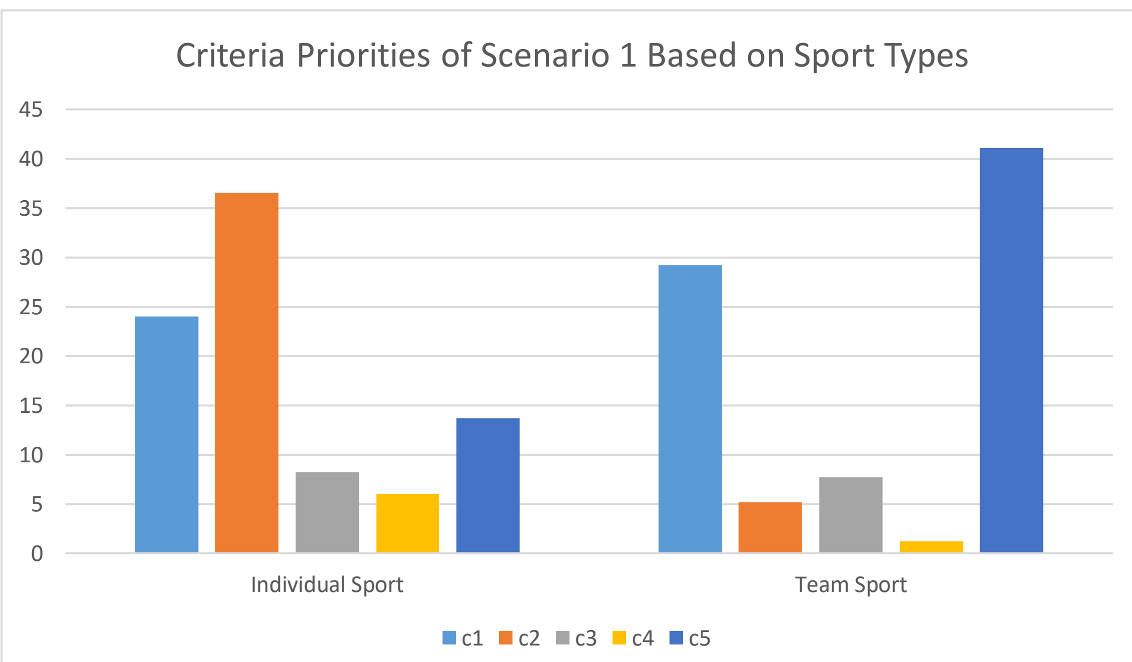

Figure 20: Comparison of criteria priorities of Scenario1 based on sport types

In Scenario 1, the healthcare professional recommends athletes not to play at the game and wait for the recovery. After all participants used decision aid tool for Scenario 1, 50 percent of athletes decide as same as the healthcare professional. However, 25% of attendees would join the competition with painkillers and 25% of athletes would participate in training with a shoulder sling. Although the participants know that if they play in the game, the degree of injury will increase, other factors like playing a championship game and earning an endorsement deal influenced the athletes' decision. Table 17 shows the summarization of percentage of participants' decision for Scenario 1.

Table 17: Participants' decision for Scenario 1

Subjects	Joining the competition with painkillers	Participating in training with a shoulder sling	Not playing at the game and waiting for the recovery
S1	14%	63%	23%
S2	70%	18%	12%
S3	6%	26%	67%
S4	12%	29%	60%
S5	31%	21%	48%
S6	7%	8%	75%
S7	8%	24%	68%
S8	6%	56%	39%
S9	31%	18%	51%
S10	10%	34%	56%
S11	66%	23%	11%
S12	53%	25%	22%
S13	20%	60%	20%
S14	8%	46%	46%
S15	9%	61%	31%
S16	73%	21%	7%
S17	8%	38%	55%
S18	70%	7%	23%
S19	10%	33%	57%
S20	22%	21%	57%
Mean	27%	32%	41%

5.1.2 Scenario 2

In addition to given five default criteria, two distinct criteria were added for the Scenario 2. These are success status and desire to return to sports. The criteria priorities based on participants are summarized in Table 19. Overall, for Scenario 2, physical condition and performance was given the highest priority weight (mean weight 36%), followed by fear to get reinjured (mean weight 30%), self-confidence (mean weight 24%), financial concerns (mean weight 22%) and stress (mean weight 12%). Other criteria were selected by participants only one time. Therefore, their mean values were not considered for criteria ranking process. Distribution of criteria data for Scenario 2 can be seen at boxplot graph in Figure 21. Other detail information like sample size, mean and median values are shown at Table 18.

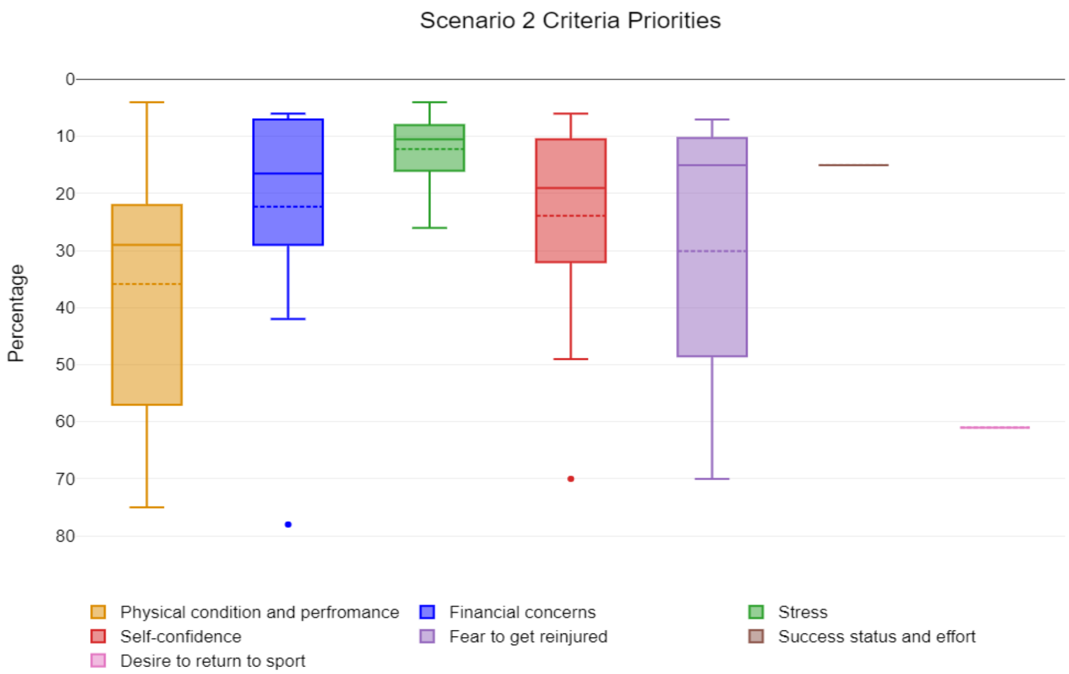

Figure 21: Scenario 2 criteria priorities boxplot graphs

Table 18: Scenario 2 criteria value analysis

Subjects	**Criteria***						
	c1	**c2**	**c3**	**c4**	**c5**	**c9**	**c10**
Sample Size (n)	20	14	10	16	13	1	1
Minimum	4	6	4	6	7	15	61
Q1	22	7	8	10.5	11	15	61
Median	29	16.5	10.5	19	15	15	61
Q3	57	29	16	32	45	15	61
Maximum	75	78	26	70	70	15	61
Mean	35.85	22.28	12.2	23.87	30.07	15	61
Outliers		78		70			

*c1 = Physical condition and performance, c2 = Financial concerns, c3 = Stress, c4 = Self-confidence, c5 = Fear to get reinjured, c9 =Success status and effort, c10 = Desire to return to sport.

In Scenario 2, the healthcare professional approves biomedical and physical healing process of athletes and allow to play in the season. However, after all participants used decision aid tool for Scenario 2, 55 percent of athletes would feel ready to play in the season. Although participants know that their injured part of the body was fully recovered, 10% of them would prefer to have a lay-off and prepare for the next season instead of playing with a poor performance. 35% of athletes would attend sports club training only and not play in the season. Table 20 shows the summarization of the percentage of participants' decision for Scenario 2.

Criteria priorities of Senario2 were evaluated based on professional level of athletes (professional and non-professional) and sport categories (individual or team sports) and the results are shown at Figure 22 and 23. The comparisons of criteria priorities were calculated based on the average of given default five criteria. According to the comparison at Figure 22, non-professional athletes prioritize self-confidence and stress more than professionals in Scenario 2. Physical condition and performance and financial concerns are little more important criteria for professionals rather than non-professional players. According to other comparison between team and individual sport players for Scenario 2, shown at Figure 23, individual sport players care more about self-confidence and fear to get reinjured than team sport players. Physical condition and performance, financial concerns and stress are more important criteria for team sport players.

Table 19: Criteria importance values of participants for Scenario 2.

Subjects	**Criteria***						
	c1	**c2**	**c3**	**c4**	**c5**	**c9**	**c10**
S1	75%	-	8%	17%	-	-	-
S2	29%	7%	15%	49%	-	-	-
S3	70%	-	-	23%	7%	-	-
S4	4%	29%	9%	13%	45%	-	-
S5	23%	7%	-	70%	-	-	-
S6	32%	11%	4%	8%	45%	-	-
S7	29%	23%	10%	38%	-	-	-
S8	23%	29%	6%	43%	-	-	-
S9	37%	30%	16%	6%	11%	-	-
S10	10%	14%	17%	-	59%	-	-
S11	23%	-	-	7%	70%	-	-
S12	26%	19%	11%	21%	8%	15%	-
S13	63%	-	-	26%	11%	-	-
S14	71%	-	-	14%	14%	-	-
S15	21%	10%	-	-	69%	-	-
S16	9%	-	-	-	30%	-	61%
S17	36%	6%	26%	17%	15%	-	-
S18	15%	78%	-	-	7%	-	-
S19	51%	42%	-	7%	-	-	-
S20	70%	7%	-	23%	-	-	-

*c1 = Physical condition and performance, c2 = Financial concerns, c3 = Stress, c4 = Self-confidence, c5 = Fear to get reinjured, c9 =Success status and effort, c10 = Desire to return to sport.

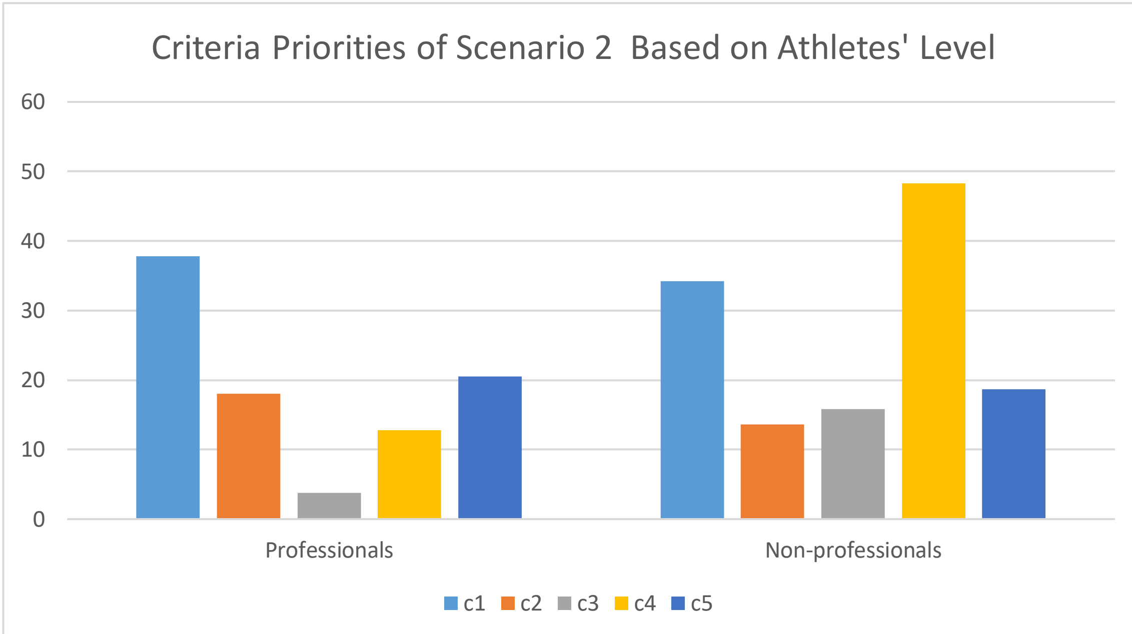

Figure 22: Comparison of criteria priorities of Scenario2 based on athletes' professional level

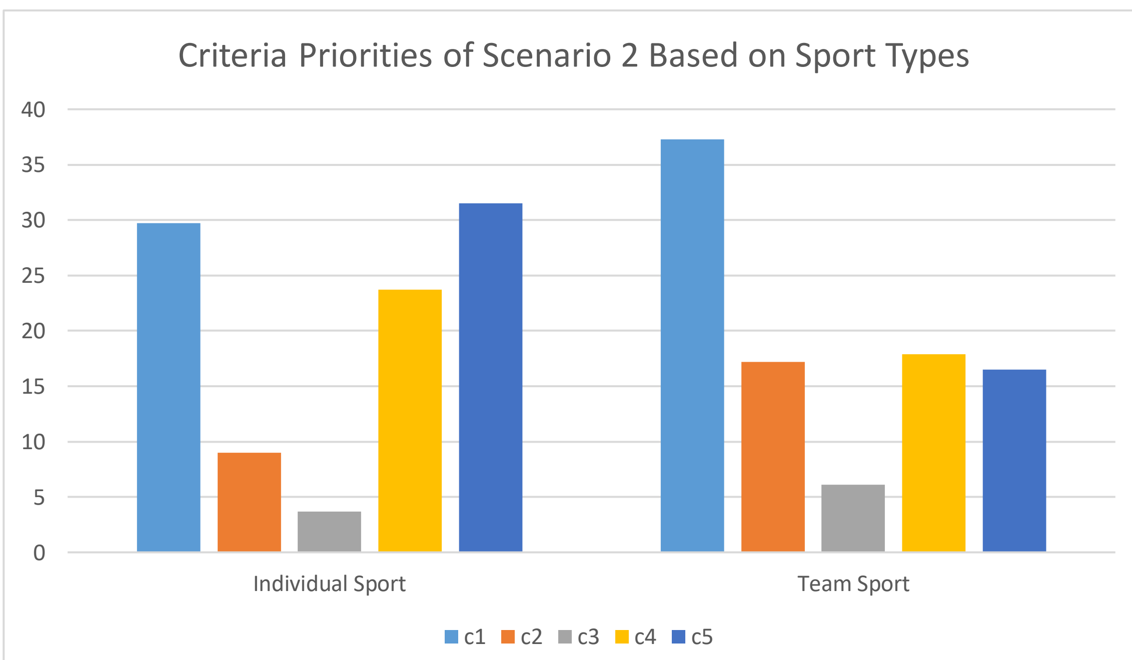

Figure 23: Comparison of criteria priorities of Scenario2 based on sport types

Table 20: Participants' decision for Scenario 2

Subjects	Playing in season despite poor performance	Attending sports club training only	Having a lay-off and preparing for the next season
S1	40%	45%	15%
S2	59%	26%	15%
S3	6%	19%	75%
S4	14%	57%	29%
S5	48%	39%	13%
S6	46%	41%	13%
S7	14%	39%	47%
S8	52%	35%	13%
S9	71%	22%	7%
S10	10%	57%	34%
S11	57%	29%	14%
S12	40%	34%	26%
S13	49%	42%	9%
S14	8%	63%	30%
S15	26%	54%	20%
S16	8%	70%	22%
S17	50%	29%	21%
S18	74%	19%	7%
S19	65%	27%	8%
S20	11%	67%	23%
Mean	37%	41%	22%

5.1.3 Tool Evaluation

All participant athletes assessed the tool and the decision process using five-point scale ranging from 1 (strongly disagree) to 5 (strongly agree). For analysis, while responses 1 and 2 are combined into a "disagree", answers 4 and 5 are merged into a "agree" category. Table 21 summarizes the results of the athletes' assessments of the tool. The proportion of participants who state that the tool was easy to use and guided them in an understandable way is 90% and found the presentation of the result in an easy-to-understand way is 100%. 80% pointed out the tool helped them to think about pros and cons of the options and 70% indicated it helped them to organize their own thoughts about the decision. 45% of athletes stated that the tool helped to identify question they want to ask their doctor. Ninety percent of participants stated that the tool made them aware of what matters most to them and the criteria that influence the decision. Finally, 75% indicated that the application prepared them to make a better decision and offered a reliable method for decision making. Some participants also answered what they like or dislike about the app and how to improve it. The answers are given below.

What people liked about the app:

- Graphical interfaces and directives,
- Clear, consistent, and unambiguous results,
- Certain alternatives,
- Helping me get to know my way of thinking, set priorities, and analyze myself.

What people did not like about the app:

- Difficult pairwise comparison process and questions,
- Forgettable scenarios,
- Being time consuming because of long thinking process.

What people suggested to improve the app:

- Using simplified comparison process,
- Reminding the scenarios when needed,
- Using real time injuries instead of scenarios or more scenarios with more detail,
- Including participants with active athlete license for more reliable results.

To get the reviews of the healthcare professionals about the developed RTP in sports decision tool, a short five-minute video about how to use the decision aid tool was prepared and shared with two clinical physiotherapists with MSc. degrees from United Kingdom. The main reason for consulting to physiotherapists in the UK was that they can directly see and consult patients. However, in Turkey, a patient has to be referred to a physiotherapist by a physician. Their evaluations about the process and the tool were given below.

Physiotherapist 1: *"...I find it a very impressive and useful way for athletes, especially, to highlight the key criteria which clinicians can then focus on prior to RTS. I think it's a good initial tool but is there a way to include progress, for example through the changes* *of strength from Return to training to Return to sport and which could then actually decipher when the athlete is 100% ready to return....”*

Physiotherapist 2: *“... Physical readiness (strength, speed, endurance measures etc. are more arbitrary measures which are 'non-negotiable' criteria to RTP, in contrast to for ex. financial gain/loss which impacts some people more than others. They could be inputted at tick boxes for the clinician's part, and as a general criterion for the athlete 'physical readiness'. So, if the athlete is worried about his physical readiness, this will show up and the clinician can re-assure the athlete.”*

Table 21: Participants' assessments of the AHP-based decision aid application

Question	Response*				
	1	2	3	4	5
Did the decision aid application provide ease of use for you?	-	-	10%	45%	45%
Did the decision aid application guide you in an understandable way?	-	5%	5%	50%	40%
Did the decision aid application show the results in an easy-to-understand way?	-	-	-	45%	55%
Did the decision aid application prepare you to make a better decision?	-	-	25%	40%	35%
Did the decision aid application make you aware of the criteria that influence your decision?	-	5%	5%	50%	40%
Did the decision aid application help you think about the pros and cons of each option?	-	-	20%	55%	25%
Did the decision aid application help you know that the decision depends on what matters most to you?	-	-	10%	60%	30%
Did the decision aid application help you organize your own thoughts about the decision?	-	10%	20%	50%	20%
Did the decision aid application help you identify questions you want to ask your doctor?	-	20%	35%	20%	25%
Did the decision aid application offer a reliable method for making decisions?	-	5%	20%	45%	30%

*1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree 5 = strongly agree. The scale was used for the first 10 questions starting with "Did the decision aid application…".

CHAPTER 6

DISCUSSION AND CONCLUSION

6.1. Discussion

Return to Sport Decision Aid tool aims to provide a practical solution to RTS decision-making process by including athletes' ignored sociological and psychological mood. The tool determines the feasibility of using AHP based on SDM concept in RTS after injury to ascertain priorities of a diverse group of people from different sports category and level. Our evaluation with 20 athletes showed that the tool offers several benefits in applying SDM with multi-criteria decision-making analysis including the following. Firstly, it has potential to solve cognitive and operative issues faced during the decision-making process. Secondly, it helps athletes to better understanding of their point of view about criteria. Also, the healthcare professional learns athletes' values and concerns which affect the decision process. It provides better communication between healthcare professional and athletes with SDM approach. The transparency of the result allows stakeholders to discuss about the decision and effected factors.

By dividing complex decision into the small managed tasks, the cognitive load of the athletes is aimed to be reduced so that, the tool can be acceptable method for the decision-making process. By addressing personal considerations, system presents a comprehensive overall assessment to aid the decision. It provides all DMs' point of view with a transparency.

There are some drawbacks that needs to be handled to improve the decision-making process. One of the features that needs to be reconsidered is pairwise comparison process. If the criteria number is high, it would be more time consuming and complex to get prioritization of the values. Also, the consistency check during the pairwise comparison can be confusing for some of the participants. As the tool required at most 0.2 consistency ratio among pairwise comparisons for both criteria and alternatives, participants are required to reconsider their evaluations till the consistency ratio is under the acceptable value. This process causes repetitive evaluation process and takes time. Although the process can take time and effort, all participants successfully completed the pairwise comparison process by obeying 0.2 consistency ratio.

The study results showed that athletes had various criteria and prioritization values while deciding about RTS. Also, different sociological and physiological circumstances influenced athletes' perspective and criteria selection process. The results of the experiments confirmed that healthcare professionals and athletes can have different viewpoints on RTS decision; and when athletes' preferences are included for the decision process, the decision result can be different than healthcare professionals' recommendations.

There are some challenges and limitations faced during the implementation of the study. Athletes from different backgrounds should use the tool and understand summarized information in an easy way. Therefore, the decision aid tool requires a user-friendly design and interfaces. The other challenge is ensuring accessibility of the tool by athletes and healthcare professionals. Athletes access to the tool and elucidate preferences before the consultation appointment. This condition required the decision support tool to be designed web based. In this way athletes and healthcare professionals can reach the application wherever there is an internet connection. Also, they can arrange an online appointment and discuss the summarized information together instead of face-to-face communication.

The study is limited within the scope of Covid-19 pandemic precautions. Because of Covid-19 pandemic, the consultation procedure which lets athletes and healthcare professionals discuss about the result for the final decision could not addressed on the study. Therefore, feedbacks from healthcare professionals for the use of the tool could not be collected.

6.2. Conclusion and Future Perspectives

In this thesis, I have proposed a tool of how RTS decision making process can be improved by considering athletes' preferences implementing SDM concept with AHP. For this purpose, a web-based Return to Sport Decision Aid tool was developed. Athletes' preference values were elucidated with the tool using AHP process with pairwise comparison method. By including healthcare professionals to the system, SDM approach was aimed. The decision aid tool provides multiple decision elements to help DMs to make better decision on RTS after injury. The evaluation with 20 athletes showed that the develop decision aid tool is easy to use and requires low cognitive load from athletes.

This thesis examined biopsychosocial effects of the injury on athletes for RTS decision-making process with two different injury scenarios. To determine the psychological and sociological states of athletes, five default criteria and three alternatives were given to the participants. Athletes can dynamically add their personal criteria to the system which affect RTS decision. Besides default factors, physical condition and performance, fear to get reinjured, self-confidence, financial concerns and stress, five other criteria were included by athletes. These are team support, recovery time, career life, desire to return to sports and success status and effort. The prioritization of these criteria is modeled to calculate by pairwise comparison method. After athletes selected their personal criteria, they compared them to identify their priority. The first research question has been answered with the experiment. Athletes who play individual sports like judo, kickbox and wrestling did not select financial concerns as a criterion. They expressed those professional athletes competing in these sport branches do not earn enough money in Turkey for their financial values to be RTS criteria. Some athletes who play team sports, took team support into consideration for RTS decision factor. The selection of other criteria was based on athletes' personal decision.

The effects of biopsychosocial state of athletes in RTS decision were analyzed with two different type of scenarios which were created in consultation with two physiotherapists. These scenarios consist of different sport injury types, various psychosocial situations and the physiotherapist's recommendation for these circumstances. The scenarios aim to assess if athletes' decision matches with the physiotherapist's advice in RTS decision. According to the experiment results, the final decision of the RTS can change based on athletes' criteria. The decision can be different than what the physiotherapist's suggested action for RTS decision. This finding answers the second research questions.

To include athletes to the RTP in sport decision, SDM approach was applied to the decision-making process. Since SDM supports mutual communications and takes athletes preferences into the account, a MCDA method was required to get DMs values. For this purpose, AHP technique was preferred to apply SDM in the RTS decision-making process. These methods were implemented with a developed web-based decision aid tool. The tool gets athletes' preferences by using AHP and creates an appropriate environment to discuss the tool RTS result in accordance with SDM. Based on the results, athletes and physiotherapists give final decision by achieving consensus about the alternatives. This organization describes how SDM was conceptualized and implemented for RTP in sport decision which is the explanation of the third research question.

The last research question has been answered by tool evaluation results. The participant athletes assessed the developed decision aid tool by answering 10 questions with five-point scale ranging from 1 (strongly disagree) to 5 (strongly agree). From the results of the tool assessment, the developed decision aid tool is a helpful and reliable method for including athletes to the RTS decision-making process. Athletes express their preferences through the tool which enables physiotherapists to learn about these criteria and performs SDM approach for RTS decision. This improves the decision-making process and provides a better environment for RTS decision.

In future studies, to improve the usability of the tool, pairwise comparison process can be simplified which shortens the decision-making process. For this purpose, hierarchical AHP structure in the form of criteria and sub-criteria can be applied to make criteria comparison process faster. Athletes selected criteria can be divided into subcategories and they can be compared based on this hierarchy. The second option for this process is using incomplete pairwise comparison method. This approach reduces the number of comparisons compared to the pairwise comparison process. The other improvement that can be addressed for further studies is tracking the injured athletes' RTS process during rehabilitation process. From the physiotherapists' perspectives, this process can be added to the system by including athletes' biomedical and functional data. Therefore, the healing process of the athletes can be tracked simultaneously with athletes' psychological and sociological states.

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APPENDICES

APPENDIX A

Appendix A.1.Ethics Permit From Metu

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
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20 MAYIS 2022

Konu : Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi : İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Doç. Dr. Barbaros YET

Danışmanlığını yürüttüğünüz Nilay YILMAZ'ın "WEB TABANLI BİR UYGULAMA İLE SAKATLIK SONRASI SPORA DÖNÜŞ İÇİN ANALİTİK HİYERARŞİ SÜRECİNİ KULLANARAK ORTAK KARAR VERME MODELİNİ GERÇEKLEŞTİRME" başlıklı araştırması İnsan Araştırmaları Etik Kurulu tarafından uygun görülmüş ve **0299-ODTUİAEK-2022** protokol numarası ile onaylanmıştır.

Saygılarımızla bilgilerinize sunarız.

Prof.Dr. Mine MISIRLISOY
İAEK Başkan

APPENDIX B

Appendix B.1. Feedback Form of Athlete

Return to Play in Sport Decision Aid Feedback Form

Thank you for using our decision aid application. We want to hear your feedback so we can keep improving our system. Please fill this quick survey and let us know your thoughts.

This feedback assesses a patient's perception of how useful a decision aid or other decision support intervention is in preparing the respondent to communicate with their practitioner at a consultation visit and making a health decision.

Some of the questions in this feedback form were created by revising the survey questions prepared by AM O'Connor. You can access the original versions of the questionnaires from the link below.
https://decisionaid.ohri.ca/docs/develop/user_manuals/UM_prepdm.pdf
https://decisionaid.ohri.ca/docs/develop/User_Manuals/UM_Acceptability.pdf

1. Please show your opinion of the decision aid application by selecting the circle to show how much you agree with each statement *

Did the decision aid application ...

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Provide ease of use for you?	◯	◯	◯	◯	◯
Guide you in an understandable way?	◯	◯	◯	◯	◯
Show the results in an easy to understand way?	◯	◯	◯	◯	◯
Prepare you to make a better decision?	◯	◯	◯	◯	◯
Make you aware of the criteria that influence your decision?	◯	◯	◯	◯	◯
Help you think about the pros and cons of each option?	◯	◯	◯	◯	◯
Help you know that the decision depends on what matters most to you?	◯	◯	◯	◯	◯
Help you organize your own thoughts about the decision?	◯	◯	◯	◯	◯
Help you identify questions you want to ask your doctor?	◯	◯	◯	◯	◯
Offer a reliable method for making decisions?	◯	◯	◯	◯	◯

2. What did you like or dislike about the decision aid application?

3. What suggestions do you have to improve the decision aid system?