# Innovation and Injury Prevention in Teaching Professional Self-Defensefor IRS Specialized Professions

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**Innovation and Injury Prevention in Teaching Professional Self-Defensefor IRS Specialized Professions**

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# Introduction

Employees of the Integrated Rescue System (IRS) often come into contact with a potentially dangerous environment. A special group consists of paramedics and thus the entire medical staff. The consequences of crisis events are a frequent cause of arrivals of the Emergency Medical Service (EMS), which must cope with a high risk of changes in the behaviour of individuals and entire groups. It can be the scene of a car accident, a sports stadium after a fight or the rubble of a house after a gas explosion. Even though these situations are not an everyday matter in paramedic jobs, the environment of emergency scenes is always unknown. Also, high patient turnover carries an increased risk of unpredictable situations. Concerns about health complications and concern for yourself or your family members can cause sudden changes in behaviour, described in real cases. Patients themselves are frequent attackers – in approximately 70 % of attacks [(95)]; patients may act under the influence of pain, alcohol intoxication or disorientation from injury. Of the total number of health care conflicts, the physical assault group accounts for approximately 20 %. In the remaining 80 % of cases, these are verbal attacks. However, these can very quickly turn into a physical attack. It can be assumed that the number of all actual cases in which a healthcare professional has been physically attacked is much higher: larger studies state that up to 60 % of events are unreported [(95)].

A number of foreign publications also deal with the topic of aggression and conflict situations in emergency care. A Slovenian study from 2015 reports the following results in a sample of 246 respondents, who are healthcare providers in the emergency medical service: 78 % of respondents confirmed verbal assault in the survey year, 49.6 % also confirmed physical assault and 26.8 % suffered physical injury by patients. 24.4 % of respondents also reported experiences of sexual harassment. Correlations were also found between physical violence and feelings of vulnerability or between physical violence and lack of knowledge about how to manage patients' aggression [(50)]. A systematic search entitled "Violence against Emergency

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Medical Staff" provides an analysis of 25 studies from nine countries between 2000 and 2016. The results show an upward trend in reported attacks on paramedics over time [(81)]. A study from two Canadian provinces with 1,676 respondents with a return rate of 89 % reveals that 75 % of Canadian Emergency Medical Service (EMS) personnel experienced workplace violence [(21)]. An Australian study of 75 EMS staff respondents reported that 82 % experienced verbal assault, 38 % experienced physical assault and 21 % experienced sexual harassment and assault [(23)]. A Polish study presents summary data from records of reports of occupational injuries within the entire staff of the National Emergency Medical Service from 2008–2012, where 6 % of injuries to all personnel were caused by attacks [(52)]. A US study focusing on paramedics, firefighters and police officers in the US reports, out of a total of 21,900 reported injuries of EMS employees, 1,100 (5 %) reported injuries due to assault [(100)]. Baydin et al (2014), mapping the issue of violence against the staff of the Emergency Medical Service in Turkey, mentions important tools for the education of medical personnel. It also draws attention to adverse psychological effects, such as post-traumatic stress disorder, unpleasant memories, super-vigilance, etc. An Australian study [(75)] mapping factors associated with violence in the workplace of paramedics also appeals in its results to the need for education and training as an important factor in prevention.

Given today's volatile security situation, it is necessary to take into account that medical staff can even face really extreme situations. Experience with real terrorist attacks has shown that security forces are not immediately able to fully predict the further progress of terrorists and that securing scenes of medical intervention is possible, but takes time. However, emergency medical emergency groups need to carry out their activities as quickly as possible and cannot wait long hours. Otherwise, there might no longer be anyone left on whom to perform a professional intervention. What matters in the first place is, of course, the life of a healthcare professional, who should not enter pre-selected risk areas. However, unexpected changes may occur that may not be predictable in advance. Interventions in isolated localities or, conversely, in areas with the presence of larger crowds of people are no exception to the work of rescuers. These bring with them additional risks in the form of negative factors of group behaviour. Interventions, especially in large cities, can also take place in the environment of hostels near large industrial zones. Employees there may be foreigners with different approaches to conflict resolutions, for example

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due to language barriers. All this and much more makes the paramedic profession challenging. Possibilities of better protection of medical staff, especially in the Medical Rescue Service, are discussed. Healthcare professionals are not covered by extraordinary legal protection that would be truly effective. Paramedics are not fully equipped with specialized means of defence, such as the police of the Czech Republic are, nor do they undergo any general specialized training in self-defence. Their uniform does not contain special protective elements (for example, protection against a cold weapon) and EMS staff members are not fully and standardly equipped with self-defence equipment.

The best way to prevent conflicts is through appropriate communication. Healthcare professionals should seek empathetic understanding of patients and respect their needs, not ignoring their message, but providing feedback. They should be able to recognize non-verbal manifestations, which can be an important signal of impending assault. It is important to learn to keep calm in communication, to be able to not react to verbal attacks, not to return them. The ability to listen to patients, give them a sense of understanding and comprehension, is absolutely crucial. Whoever can do this significantly reduces risks of physical conflict. Even so, risks cannot be completely avoided. When this happens, the first reaction should not be a conflict, but an attempt to de-escalate tensions with a subsequent retreat. In terms of tactics, paramedics should not enter a scene where there is a reasonable suspicion of physical aggression without the close cooperation and support of other designated components of the integrated rescue system – the police of the Czech Republic. However, there may be situations where an attack cannot be predicted. A number of factors can interfere: a wrong estimate, a moment of surprise in the form of a quick, violent attack as a result of a sudden change in the behaviour on the part of attackers, the involvement of a paramedic by their professional intervention. These are situations where there may be an imminent threat to life. Paramedics can also defend their loved ones, which can force them to take self-defence action. In some cases, early intervention can protect aggressors themselves – a patient who threatens, for example, self-harm. Not all conflict situations can be resolved with the help of communication strategies, and even for such scenarios, health professionals should be prepared. An attacker can be a determined, unpredictable, "psychiatric" and, in the worst case, armed aggressor. Not always, but mainly not immediately, is a patrol of the police of the Czech Republic nearby, and


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defenders may be faced with the question of how to protect themselves without outside help. Students of study programmes focusing on security issues and jobs under the IRS may also encounter conflict situations within their professional traineeships.

The system of professional self-defence[1] is a set of tactical and technical procedures for resolving conflict situations. However, the training of medical staff is specific and differs from regular courses, where the teaching can be spread over several months or years. Healthcare professionals need to be trained in the short term. This leads to a shortening of the content of the curriculum and thus to a shortening of the time during a course to master a number of important movement responses related to safety. For example, there is no time to thoroughly master the correct technique of falls. Another specific feature of the training of medical staff is their initial level of experience, which, in contrast to the professional environment of self-defence courses, is low. While commercial courses may be sought after by candidates who already have some experience with combat systems, these will be exceptions among medical personnel. People inexperienced in sport may face a number of not only physical, but above all mental barriers. They do not know the performance possibilities of their bodies, in contrast to people who have some elementary experience with a sport. They may have an exaggerated fear of failure and injury, or they may not be able to estimate their physical capabilities. They have not developed basic sports habits, such as diet discipline before training or a good drinking regime. In conflicts targeted under healthcare professional self-defense techniques, attackers are most often patients themselves; these, however, must not be injured by physical actions. All of this places additional demands on a deeper understanding and mastery of the techniques, which, however, must be mastered in a short time. For these reasons, the training programme must be adapted so as to take into account and prevent these risks.

The main objective of this publication is to prevent injury risks during the teaching in professional self-defence courses for students of secondary schools and universities. The publication is intended for university teachers responsible for study courses, and tactical coaches, as well as secondary

[1] Wording is based in Czech societal climate – self-defense maybe outside Czechia understood as passive tool for saving own life, a last resort. Active tools to resolve conflict situations are part of “law enforcement” techniques, which are supposed to be more active tools (Mgr. Jaroslav Šíp).


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Figure 1. Teaching the combat system

school and university students. The publication should provide its readers with insight into broader educational contexts in injury prevention during professional self-defence courses and, in a comprehensible way, present the biomechanical principles of frequent movement actions and measurement results in implemented studies focusing on the evaluation of impact forces in combat systems. Modified and updated information from a number of measurements can be used especially by teachers who want to expand their knowledge in the area of self-defence theory and apply it to teaching their students. Selected information from various areas of combat systems can make it easier to understand broader aspects of training and sports preparation. The publication also presents the results of an injury rate survey in the teaching of special physical education in one selected secondary school with a focus on safety, and also methodological tools to increase student safety during the teaching in professional self-defence courses, including recommendations for first aid. The last chapter proposes an innovation of training in the form of a methodological series which represents the potential for reducing injury risks in training respecting the performance possibilities of participants in self-defence courses for healthcare professionals.

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◀
Figure 2.
Pair exercises in the karate system – oicuki strike technique


▶
Figure 3.
Pair exercises in the judo system – ogoshi throw technique

◀
Figure 4.
Pair exercises in the aikido system – sankyo leverage technique


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# 1. chapter
# **Injury Prevention in Educational Contexts**

*Every professional self-defence training programme should provide its students with a safe environment in order to minimize injury risks. The most important issue is primary prevention, which includes all measures that can be taken before the actual implementation of teaching. Measures can be divided according to whether these focus on the formal or content side of teaching.*

Form (Teacher):

- Categorizes students
- Sets rules in pair exercises
- Requires selected discipline elements
- Supervises dojo rules
- Regulates selections of pairs
- Requires accident reporting

Content (Teacher):

- Sorts learning contents from simple to more complex
- Adheres to preparatory exercises
- Eliminates techniques with a high risk of injury

Everything that takes place in the training of self-defence movement actions is related to the human body and is subject to the laws of nature. However, the personality of individuals has a significant share here: everyone conditions their physical performance with their free will and controls the course of their physical performance according to their character, attitude and other characteristics.


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## 1.1 Form

### 1.1.1 Student Categorization in Professional Self-Defence Training

Steps to a safe course of self-defence training must already be taken in the planning period. Teachers may vary in their levels of experience. When preparing the content composition of a course, it is necessary for teachers to assess one's students‘ profiles and adjust the complexity and requirements of the entire course and its content accordingly. Experience from practice shows that varying levels of experience are a big problem: there are groups of students composed of both people inexperienced in sport and athletes experienced in various sports or even, in exceptional cases, professional martial athletes. This means that while some students are unable to estimate the limits of their bodies and have not acquired important sports habits, some students tolerate the training load, but may not know the specifics and risks of self-defence movements. A small number of students may have a very good knowledge of self-defence physical actions due to their experience in martial arts competitions, but they may not be able to estimate the level of experience of their colleagues, especially in pair exercises. Generally, teachers' individual approach is important, as they have the crucial role in identifying risks of injury in advance and preventing injuries.

Table 1. Participant categories

| Participant categories | Description |
| --- | --- |
| Beginner | Has no experience with a combat systém or any other type of sporting activity. |
| False beginner | Has basic experience with a combat system or other type of sporting activity for a minimum duration of 6 months. |
| Advanced | Has mastered basic self-defence reactions, can respond to an attempt at destabilization by changing their posture, masters the fighting posture, knows some techniques in posture and non-posture combat, can apply them in improvisation, controls their movement during exercise. |
| Professional | Has many years of experience in martial arts competitions or has achieved education in a system of self-defence or in a system of martial arts at the dan level or at the instructor level. |

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Figure 5 a, b. Professionals in Aikido prefer contact where it is possible to create any technique.

### 1.1.2 Pair Exercises

Acquisition of physical actions in self-defence systems most often takes place in pairs. This also applies to martial arts or martial sports systems. Only in exceptional cases, in the so-called *kata* or shadowing (drilling of movements of strikes and kicks into free space without a partner), is it an individual exercise (only one person does the exercise). Most often, however, one of the partners plays the attacker (*uke*), the other is the defender (*tori)* and together they form a pair where essential learning takes place.

As part of the training, the *uke* simulates prescribed types of attacks and the *tori* responds to them with self-defence reactions and techniques. In pairs, there are interactions that allow gradual acquisition of grasps, grips, strikes, kicks, blocks and related self-defence actions. These interactions always present a certain degree of injury risk. Beginners often cannot guess the effectiveness of their physical actions and often underestimate them. They also often confuse pair training with competition and want to defeat their partner. They reckon that movement action training is a sort of open fight. Therefore, an important step to increase safety in training is the teacher's obligation to clarify the mutual roles of both partners. The *uke* is the one who attacks (catches, kicks, pushes, strangles, etc.), and the *tori* performs self-defence movements (self-defence techniques).

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Figure 6 a, b, c, d, e. Uke and tori

Who is more important in a pair? At first glance, the *tori* may seem to be more important. The *tori* performs self-defence movements evaluated afterwards by the teacher. On closer inspection, however, the *uke* has an equally important role: the *uke* provides adequate resistance to the *tori* and points out technique weaknesses to the *tori* using appropriate means. In a certain sense of Eastern philosophy, the *uke* is the more important one and is referred to as a teacher or a guide.

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Practicing self-defence techniques is not a real fight, but a simulation. Both partners accept the game rules as a means to safely master complex movement patterns. The game allows not only a mechanical simulation of specific movements, but also a living experience of the atmosphere. It is possible to increase the power of the living experience by various mechanisms. These include, for example, a verbal simulation before the conflict phase itself (attackers verbally attack defenders before the actual attack). Game mechanisms can also be used when training areas change and practicing takes place in a real environment (for example, the ambulance environment in the case of professional self-defence for paramedics). It is important for the partners in pairs to demonstrate mutual respect. Formal habits also contribute to this; these can include, for example, a short bow before and after the end of the training sequence.

### 1.1.3 Training Discipline

Training simulations of self-defence actions lead to tense conflict situations and cannot do without emotions. These may tend to increase rapidly and uncontrollably during exercise. A teacher's task is to control and maintain the level of emotions at a reasonable level. However, students are not robots, but human beings. The aim of the following recommendations is not suppressing human emotions, but ensuring their adequate regulation. The practice of martial systems, especially traditional Japanese martial arts, is strictly determined and limited by a variety of procedures, practiced habits and tools of etiquette. However, it is not appropriate to apply the whole scheme to people inexperienced in sport, whereas this is typical for professional sports clubs. For example, bowing before entering and leaving the *dojo* will be of no benefit to students during training sessions. The same is true about evaluation ceremonies and starting rites at the beginning of training sessions (for example, bowing in the direction of various signs or pictures of the system founders). However, this does not mean that teachers need not be aware of the power of instruction, which allows them to put students to an optimal mode. Such a mode supports individuals' motivation to learn new things, and the determination to overcome fear, especially fear of failure. Moreover, it moderates aggressive tendencies, efforts to find quick solutions without a patient approach and the tendency to want to achieve victory at all costs.

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Figure 7

### 1.1.4 *Dojo* Etiquette – Training Area

A place for self-defence training, whether it is a standard gym, a surface-treated gym or another improvised room, should be considered a "different" space. This means that different rules apply here than, for example, in school classrooms. Attacks on the human body are simulated here. Therefore, respect for this space is the first step in setting students' behaviour correctly. Passive safety is especially important in the form of respect for the training surface, which should remain clean and should not serve as a storage place for personal belongings. Experience shows that students often place various personal items on the edges of the *tatami,* and this can disturb attention and increase the risk of falling. Teachers should dedicate a special space for students' personal belongings.

The mode of entering and leaving the dojo is closely related to the dojo rules. Student who arrive in training after the lesson has started (late arrival) should always report their arrival to the teacher before starting exercises. This procedure is even more important if a student leaves the dojo during the exercise. Teachers must give participants permission to leave the lesson and thus prevent situations where students possibly leave the *dojo* due to an injury and would thus be left unattended outside the dojo.

A lesson should never begin with a simple "let's begin" statement. It is important that there is enough time for students' mental setting. Students

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Figure 8

Figure 9. Breathing exercise Kókjů

Figure 10

come to the exercise area from an external environment that can be stressful. Starting lessons with a short positioning at a designated place in the *dojo* with possible breathing exercises allows students to get an optimal mindset.

### 1.1.5 Choice of a Pair

For practical reasons, teachers should make students create pairs with a partner of approximately the same height and weight. Anthropometric balance results in better compatibility of movement tasks, affects success in mastering individual techniques (such as shoulder throws) and


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Figure 11. The levers of small bones are a common cause of injury

Figure 12. Tomoe nage

minimizes possible injuries caused by a much heavier partner falling on the other.

### 1.1.6 Reporting Injuries

Before starting actual exercises, teachers should check students' possible health restrictions. If they do not do so, they risk inappropriate selection of a student, with a medical restriction, for a demonstration, or unnecessary punishment of a student during an exercise. It can happen that a student avoids certain exercises due to pain, limited mobility and the like. In the case of health restrictions that allow it, the teacher and the student agree on a joint compromise in the form of adjusting the exercises so that the student can complete the course. Likewise, after the exercise, students should be asked by the teacher to report any injuries. If the injury occurred during the lesson, the teacher must document the injury.

## 1.2 Content

The curriculum of teaching professional self-defence for health professionals can hardly cover the whole curriculum common in commercial systems of self-defence or in study courses of special physical training ending with an end-of-study examination. Time requirements do not allow the curriculum to be spread over several months or years. Teaching

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Figure 13. Preparatory exercise for the kote gaeshi technique: a – Both the defender and the attacker implement the technique without a grip, only by palm contact. They must not lose the contact during the whole technique. This requires slowing down all movements. At the same time, the attacker can adjust their fall using a technique according to their own needs. b – The defender and the attacker implement a complete technique with a grip.

contents for training touches, grabs, strikes, kicks, attacks on sensitive places, stance combat, falls, blocks, etc. must be effectively shortened and targeted at specific needs. Teachers must understand and respect this important aspect. Otherwise, they would increase risks of injury, especially in the case of techniques whose prerequisites, due to their complexity, include the mastery of several physical actions at the same time.

### 1.2.1 Preparatory Techniques

Teachers must organize the teaching content from simple to more complex parts. Each complex movement action should also have its own preparatory technique. This is a simple fragment of movement that targets the key and also the riskiest part of the whole technique. After safe training of this core fragment, students can try to practice the whole movement pattern.

Preparatory combats are relatively simple physical exercises, whose mastery is important for further drills within combat sports [94]. They have anr irreplaceable role, especially where the defender fixes parts of the attacker's limbs and determines the effect of the whole action with their own movement. In many such techniques, there is a risk that the attacker will

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speed up their action so much that the defender cannot react to it. In such cases, the entire movement sequence must first be drilled without any risk of injury.

Teachers should exclude from the set of techniques those that show a high-risk factor of injury. The identification of such techniques depends more or less on the educational goals and overall conditions of the training. With a short-time allowance for training, it is not possible to pay enough attention to preparatory exercises that are necessary, for example, for judo throws, complex leverages, or techniques composed of several complex movement actions.

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# 2. chapter
# Biomechanical Principles in Teaching Professional Self-Defence

*The central point of teaching self-defence movement actions is the human body, which is subject to the laws of nature. These laws can be examined within the scientific field of physics, especially mechanics and biomechanics. Physical laws within self-defence movement actions can be understood as the movement of bodies in space and time, where the human body is divided into individual segments. Specific relationships between these can be identified through basic quantities: length, time and mass; and through derived quantities: speed, acceleration, force, pressure, etc. Movement actions in self-defence, martial sports or martial arts carry with them a certain potential that is applied to an attacker in a real conflict or to an opponent in a martial arts competition. As a result, any training preparation poses certain risks of injury. Good knowledge of the physical properties of physical actions, especially for striking actions, allows you to create preventive tools that reduce risks of injury to a student or a combat athlete in training.*

## 2.1 Measurement of Physical Properties of Movement Actions

Practicing movement actions of any combat system poses a degree of risk of injury to the human body. In general, in the case of complex martial arts systems, such as Mixed Martial Arts (MMA), medical associations significantly monitor them due to the high level of trauma [116]. The MMA system is considered a martial sport where athletes in competition can use a wide range of techniques from various disciplines of martial sports and martial arts. This complexity also occurs in self-defence systems, which also provide defenders with techniques of strikes, kicks, throws, knockdowns,


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Figure 14. Methodological demonstration of the risk of tissue deformation after the impact of a strike

shoulder throws, leverages and more. For this reason, transfer of experience from a complex sports system to self-defence systems is possible. On the other hand, sports systems differ, mainly in their goals and also in tactics. All athletes want to win, and aggressive attacking techniques especially pose a substantial risk of injury [(68)]. MMA athletes showed demonstrably greater experience with MMA injuries (typically bruising), compared to boxing [(68)]. MMA reports even higher rates of traumatic brain damage than American football, ice hockey or other contact sports [(49, 61)]. The incidence of injuries in MMA seems to be even higher than in most, if not all, other popular and commonly practiced martial sports [(77)]. Contrary to this, Curran-Sills & Abedin (2018) report that MMA has not caused the

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Figure 15 a, b, c, d, e. Kistler force platform – combat athlete during the measuring of peak force for an elbow strike in the ground and pound positions[2]

same exposure to concussion over the last 10 years as in other popular sports (ice hockey, American football, rugby) and similar simplifications should be avoided given the methodological differences between different studies. Despite the ambiguity as to which sports systems and which combat sports systems are the riskiest, the MMA-style way of fighting certainly is among the imaginary front ranks, due to the significant absence of protective equipment and freedom of rules. Street fighting without rules and without any protective equipment can be considered the next stage. The MMA system is therefore the ultimate sports system where it is possible to evaluate possible risks of injury for specific physical actions, for example, with the help of statistics from combat competitions. As already indicated, studies from which the latest scientific knowledge regarding risks of injury can be drawn most often target the environment of martial arts systems. Injuries occur in competitions; such injuries can be described and classified, and we can search for connections between a physical action and an athlete's injury in order to design preventive measures. The vast majority of studies report measurement results within simulated laboratory conditions, where combat athletes perform a movement action according to predetermined conditions. Some studies, however, have also obtained results from measurements during real combats. Conclusions of these findings may point out the most common types of injuries associated with particular physical actions, including their potential for injury.

### 2.1.1 Direct and Indirect Force Measurement Across Different Designs

Studies that focus on measuring movement actions in combat systems mainly describe achieved values of force and speed. The value of force is

[2] Ground and pound: combat tactics in the MMA system.

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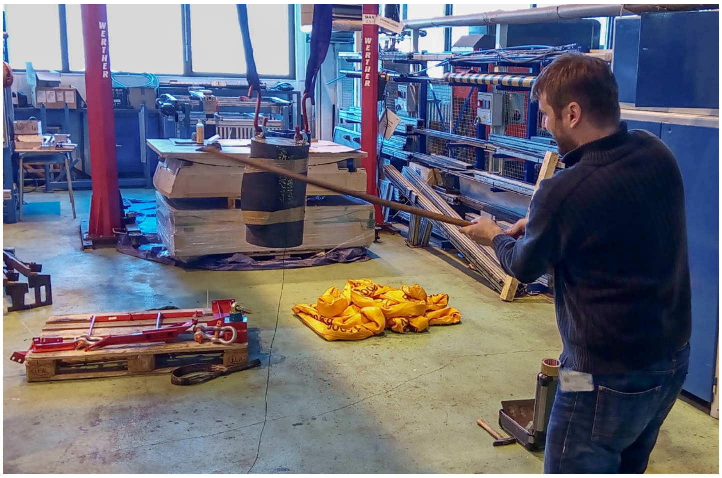

Figure 16. Ing. Petr Votápek, Ph.D. performing a rod strike onto the measuring apparatus

monitored mainly in movement actions like strikes and kicks and can be measured directly or indirectly. Direct force measurement is very accurate and can be implemented when using specialized platforms, for example, from the American manufacturer Kistler.

These are rigid plates with built-in piezoelectric units (crystals) which work on the principle of generating electrical voltage during their deformation. Such sophisticated platforms with a preference for measurement in dynamic applications (69) have the highest degree of validity and are suitable equipment for direct measurement of such data (47). Indirectly, the force can be measured using various methods, for example, with the help of separate accelerometers (3,122,128,71). These can be placed in the athlete's clenched fist or attached to his/her limb. In another measurement design, accelerometers are mounted on a suspended load of known mass (8) which an athlete strikes, kicks or strikes with an object.

In such cases, the value of force must be calculated backwards with the help of data on the measured acceleration of an object and its mass. Another possible way is using force sensors (cells) based on tensometers (107, 60) which measure the deformation of an inner component of known stiffness. Force can also be measured using the kinematic method with the help of

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high-speed cameras (114, 53, 35), where the position, especially depending on time, is recorded and subsequently read. In such a case, it is necessary to have information on the exact mass of the moving limb segments in order to calculate the force. Most often, however, measurements are performed using a combination of the described methodologies (91). Table 2 provides a summary overview of measuring sensors in 28 studies, where forces (F) and velocities (s) of strikes in combat systems were measured.

Table 2. The measurement equipment details used in selected studies
(Beránek et al, 2020)

| **Authors** | **Measuring sensor** | **Details** |
|---|---|---|
| de Souza et. al., 2017 | Tensometer<br>Load cell | Model ZX 5T, Alfa Instrumentos Eletronicos, Ltda |
| Tzyy-Yuang et al., 1999 | Accelerometer | 3 axial, sampling rate 1000Hz |
| Gianino et al., 2010 | Camera | Frequency 25 frames a second |
| Daniel et al., 2014 | Camera | The Quintic information system |
| Rinaldi et al., 2018 | Camera | Optoelectronic motion analysis system SMART-DX6000 System, BTS, Milan, Italy (8 infrared cameras) |
| Cesari et al., 2007 | Photocells | 50 Hz |
| Bolander et al., 2009 | Accelerometer<br>Load cell<br>Camera | Model 7264D, Endevco Inc.<br>Model 7120 Syscon Inc<br>HG-100K, Redlake Inc. |
| Neto et al., 2009 | Load cell<br>A Tekscan high speed pressure sensor<br>Camera | Model 7120 Syscon Inc.<br>Model 9500<br>HG-100K, Redlake, Inc. |
| Walilko et al., 2005 | Tekscan pressure sensor<br>Accelerometer<br>Load cell<br>Camera | Boston, MA, M 9500<br>Seven Endevco (San Juan Capistrano, CA) 72642000<br>A six-axis upper neck load cell (Denton ATD, Rochester Hills, MI)<br>Kodak HG2000 |

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| | | |
|---|---|---|
| RatTong Iam et al., 2017 | Forceplatform<br>Camera | Kistler 9286BA<br>Qualisys Oqus 7, Qualisys AB, Sweden |
| Loturco et al., 2016 | Forceplatform | A force platform 400 Hz with custom-designed software (Accu-Power; AMTI, Graz, Austria) |
| Chadli et al., 2014 | Accelerometers<br>Tenzometer | A new punch analysis tool for boxers |
| Busko et al., 2016 | Accelerometer | Tri-axial |
| Bružas et al., 2015 | Forceplatform | Kiktest-100 |
| Halperin et al., 2017 | Load cell<br>Camera | Infra red LED Vishay |
| Halperin et al., 2016 | Load cell<br>Camera | Infra red LED Vishay |
| House et al., 2015 | Force sensor | Tekscan, Inc. Boston, MA |
| Dyson et al., 2005 | Force platform | Kistler 330 Hz |
| Cheraghi et al., 2014 | Camera | Kodak Motion Corder Analyzer, SR series |
| Bingul et al., 2017 | Camera | Oqus 7+ |
| Kimm et al., 2015 | Accelerometer | |
| Pierce et al., 2006 | Force sensor | Force measurement systém U.S. Patent No. 5,449,002 |
| Svoboda et al., 2015 | Force platform<br>Camera | Kistler 9281<br>Redlake HG 100 |
| Smith, 1983 | Camera | 100 frames / second |
| Atha et al., 1985 | Accelerometer<br>Camera | camera 16 mm, 64 Hz and Hycam rotating prism camera 400–1500 Hz |
| Čepulénas et al., 2011 | Force platform | Kiktest-100 |
| Neto et al., 2012 | Load cell<br>Camera | model 7120 Syscon Inc<br>HG-100K, Redlake Inc. |
| Neto et al., 2008 | Camera | Motion Scope PCI, Model 8000s, Red lake, USA, 1000 Hz |

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Figure 17. a, b – connecting the sensor with a cable or kinematics markers can limit the athlete's movement during the measurement), c – in another measurement design, the measuring sensors also limit who performs the test on the measured athlete).

Every measurement design, be it power platforms, accelerometer and tensometer sensors, high-speed cameras or innovative devices (such as a punching bag with built-in sensors), poses certain risks of intervening variables. These are measurement errors that can be both on the side of the measuring apparatus and on the side of the measured individuals. One of the reasons may be that the conditions in which a martial athlete performs movement actions as part of laboratory measurements are different from the standard real environment. The most common problems include restricted movement and the athlete's disturbed concentration due to the presence of cables, which are necessary for connecting the sensor on the athlete's body and the recording device [40]. In the worst case, cables are not long enough and may directly limit the range of movement of a limb during a performance measured. Even when cables have a sufficient reserve, athletes still feel them on their body, which can affect their movement performance. The ideal solution is wireless data transfer between the sensor and the recording device, but such technologies are not always available.


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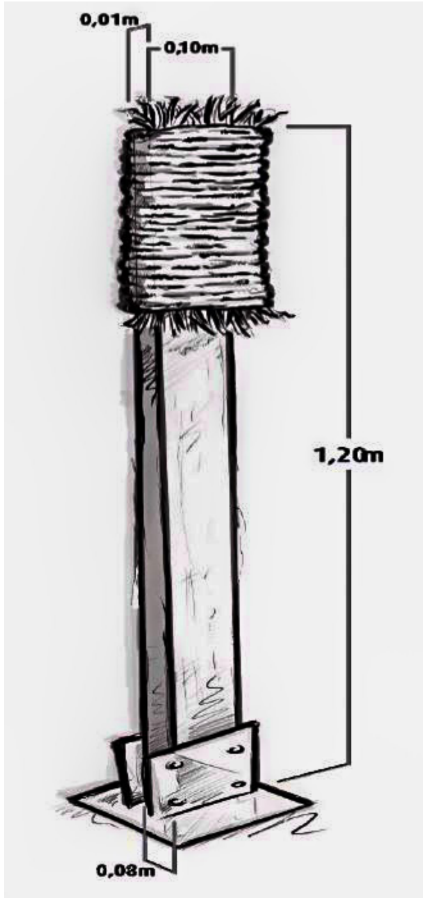


Figure 18 Makiwara (de Souza, 2017)

If the sensors are part of the impact platform and the athlete's limb hits it directly, it is necessary to provide the impact surface with a suitable damping material, for example, based on polyurethane foams, which can protect athletes from injuries. Failure to do so could result in serious injury to the limbs, as the measuring platforms are usually made of rigid materials. The standard is also a firm anchoring of the platforms, for example to a wall or to the floor without the possibility of the board moving when it is hit. However, the damping foams which must be used for these reasons affect the effect of the impact of the hand on the target and thus the measurement result. It is also difficult to estimate what damping effect needs to be achieved to fully protect the athlete during the measurement. An excessive damping layer, on the other hand, can cause unexpected deformation of the impact surface upon impact of the limb and can damage joints, ligaments and the like. In any case, when hitting a rigid board, athletes are always in a certain mental discomfort, no matter what protective equipment is used. The only exception is measuring sets which use a real punching bag with built-in sensors (26). However, there is a problem with the exact determination of the attenuation of protective material in relation to the actual results. A certain compromise is reported in a study by Souza et al. (2017), where the measuring device was a traditional aid in the karate system “makiwara” with built-in sensors. The hard impact surface, consisting of a wooden board and a rope coiled around the wood, did not contain any other dampening surfaces, but from the point of view of safety it was a standard training aid. In this

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way, however, it is only possible to measure combat athletes who are used to striking thus modified areas without the use of gloves (primarily the karate system).

The highest level of comfort with regard to injury risk during measurements is probably provided by kinematic analysis using high-speed cameras. Athletes do not come into contact with any material object, perform a movement action in the form of shadowing[3], and the high-speed camera records the trajectory of the movement of the individual markers attached to the athlete's body. Based on the record analysis, it is possible to determine the acceleration of individual markers. For valid calculation of force, it is necessary to know the exact mass of the moving limb. However, this consists of several segments, which move at different speeds during the strike and with different accelerations, and it is also difficult to determine the exact mass of the limb for a particular athlete.

It does not seem at all easy to put together an ideal measurement design, and this in turn confirms why many studies use several measurement technologies in parallel. The reasons for this are both the cross-checking of measured values and a larger range of coverage of measured physical values with regard to different measurement accuracy.

### 2.1.2 Dynamic and Impact Attenuation of Dampening Foams

An interesting issue in connection with the measurement of movement actions of strikes in combat systems is the use of protective aids, most often gloves. From a certain point of view, their presence on the hands during the measurement of impact forces affects the results. On the other hand, gloves are an integral part of an athlete's performance in many sports systems and as such should be included in the overall measurement, especially for boxing sports systems, etc. It is not possible for gloves not to be part of an athlete's natural performance.

From the perspective of teaching professional self-defence, gloves provide an opportunity to protect students in training. What effect will the use of such equipment have on risks of injury? In their study, McIntosh and Patton (2015) assess the effect of a head protector on an athlete's health.

[3] Application of movements, usualy strikes, in empty space.

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Figure 19. Type of gloves used in the boxing system
Figure 20. Type of gloves used in the MMA system
Figure 21. Type of gloves used in the karate system

An impactor housed in a standard glove was used, which led the impact into a head and neck system dummy with and without the AIBA head protector. The impacts reached speeds of 4.1–8.3 m/s[4]. The maximum impact forces ranged from 1.9 to 5.9 kN. The results showed that protection of an athlete's head in combination with gloves can play a crucial role in the protection of the athlete. For slower strikes with a speed of less than 5 m/s, protective equipment had no significant effect. At higher strike speeds between 5 and 9 m/s, head protection in combination with gloves offered a high protection level to a boxer's head. For a clenched fist punch, average results of acceleration without protection were 130 g[5] compared to 85 g for head protection in a frontal impact. In the case of acceleration of the head in a side impact, the differences between values without head protection and with head protection were approximately 50 %.

In the study "Strength and speed of upper limb impact in combat sports: systematic research and meta analysis" (Beránek et al. 2020), some studies involved measuring movement actions using gloves, other studies measured movement actions without gloves or gloves were not reported in the measurement methodology (Table 3).

Information on exact measurement conditions is important because the use of protective equipment during measurements certainly affects measured values of impact forces in the target. In order to make results from measurements of one combat system applicable to another system, it is important to always exactly respect the measurement methodology. For

[4] m/s = meter per second is a unit of speed.
[5] 1 g = 9,81 $m/s^2$


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Table 3. Overview of using sports gloves during measurements

| | |
|---|---|
| **Studies for F mean** | |
| de Souza et. al., 2017 | No gloves |
| Bolander et al., 2009 | No gloves |
| Neto et al., 2009 | No gloves, Protective pad |
| Loturco et al., 2016 | Competition gloves with protective pad (estimate for protective pad 3 %) |
| Chadli et al., 2014 | Gloves |
| Busko et al., 2016 | Bandage + gloves |
| Pierce et al., 2006 | Gloves |
| Neto et al., 2008 | No gloves |
| **Studies for v mean** | |
| Cesari et al., 2007 | No gloves |
| Cheraghi et al., 2014 | Gloves |
| Kimm et al., 2015 | Gloves |
| Smith, 1983 | Gloves |
| **Both** | |
| Neto et al., 2012 | No gloves, Protective pad |
| Walilko et al., 2005 | Gloves |
| RatTong lam et al., 2017 | N/R for gloves |
| Bingul et al., 2017 | N/R for gloves |

example, in self-defence systems, strikes occur in real situations without protective equipment [46]. This means that strike effects would probably be higher than those measured in martial arts with protective equipment. On the other hand, measurements of inverse dynamics take into account the total energy contribution into the impacted object, and most athletes, in studies that reported Fmax, used boxing gloves during measurements [3, 26, 42, 65, 64, 60, 57, 78, 99, 112, 122]. Pierce et al. (2016), who reported the highest value of impact force (5.4 kN), measured athletes during real boxing matches; Walilko et al. (2005), Atha et al. (1985) and Dyson et al. (2005) used boxing

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gloves in laboratory conditions. It is assumed that gloves are designed to reduce the pressure during the impact due to the increased impact area and, at the same time, a partial decrease in kinetic energy due to elastic deformation of glove fillings. This reduces risks of injury (108). However, the studies included do not comment on possible risks of distortions during the loss of measured force. The reason may be that boxing gloves are considered a natural part of an athlete's performance, but also the complicated methodology of measuring attenuation for individual protective aids. Only one of all reported studies (78) estimates the dampening effect of the equipment at 3 %. Due to insufficient reports on how selected foam, specifically foam intended to cover the impact area for a strike, affects the value of the impact force upon impact, we performed our own measurement [6]. Several tasks were addressed, namely the determination of dynamic and impact attenuation and the determination of dampening properties during deformation for special dampening foam used for the treatment of sports surfaces for martial arts. It was necessary to get acquainted with the EN 1177 regulation, which specifies test equipment and impact test methods for determining dampening properties of the surface by measuring the acceleration at impact. Test equipment complying with this regulation is applicable to tests performed in laboratories or at installation sites. The regulation compares results obtained with the help of accelerometers with the tolerance of brain tissue to acceleration.

The measurement of the attenuation of the Trocelen board polyethylene foam took place in 2019 in the laboratories of the Faculty of Mechanical Engineering of the University of West Bohemia. In the first step, the hardness of both sides of the damping foam pad was determined.

The hardness was determined using the Durometr Type A hardness tester (according to DIN 53505; ASTM D 2240; ISO 7619).

The measurement of dynamic attenuation of damping foam material was carried out using a measuring system (accelerometer, amplifier, SW SPURT) for dynamic measurement of vibrations, determination of natural frequencies and vibration intensity. The aim of this measurement was to determine the natural frequency and relative attenuation using impact excitation. Required values were only determined after the transformation

[6] The measurement was carried out and published by Doc. Ing. Josef Formánek, Ph. D at the Faculty of Mechanical Engineering at the University of West Bohemia in Pilsen.

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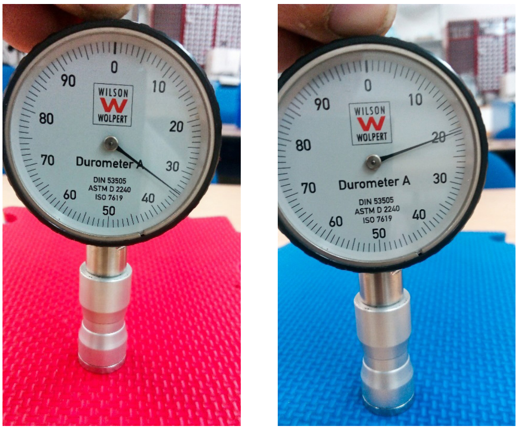
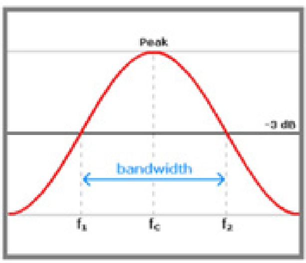



Figure 22, 23. Measurement results (red side 35, blue side 20)

of the dynamic measurement results into an amplitude-frequency characteristic, which was performed using the Fourier transformation. The value of relative material damping was calculated from the values of natural frequency and relative attenuation. The Q factor represents quality factors of the system and is not directly proportional to damping factor. The nominal bandwidth at the height of A/ (or at a decrease of 3 dB) and the natural frequency are used for its calculation [82].

Diagram 1: Determination of bandwidth




Q factor:

$$Q = \frac{1}{2 \cdot b_p}, [-]$$

$$Q = \frac{f_c}{\Delta f} = \frac{f_c}{f_2 - f_1}, [-]$$

$$Q = \frac{19{,}49}{23{,}21 - 17{,}86} = 3{,}642$$

$$Q = \frac{1}{2 \cdot b_p} \approx b_p = \frac{1}{2 \cdot Q} = \frac{1}{2 \cdot 3{,}642} = 0{,}137$$

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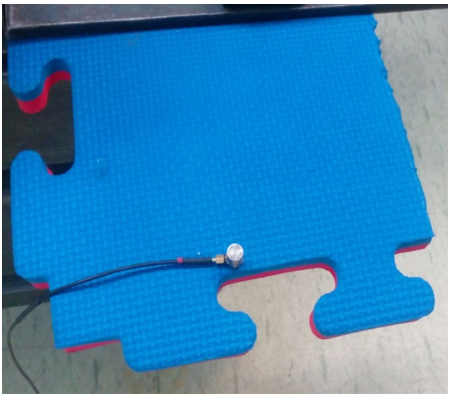 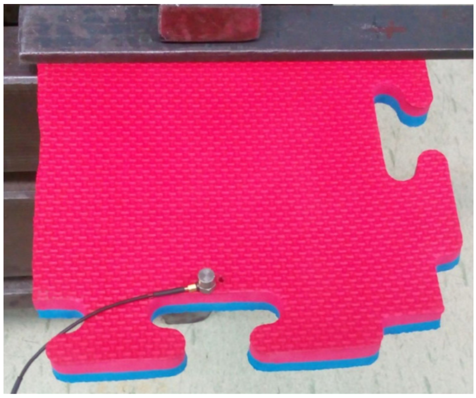

Figure 24. a, b – total workplace for measuring natural frequencies and location of sensors A and B

Specification: Damping factor $b_p$ can be determined from the nominal bandwidth to height of 1/√2 resonant peak and from natural frequency $f_0$ in the form

$$b_p = \frac{f_2 - f_1}{2 f_0} .$$

Relative attenuation is expressed as a percentage and therefore **$b_p$ = 13.7 %;** the system can be described as damped for dynamic effects of vibrations. The measurement of impact attenuation of the material was carried out with the help of a measuring system (accelerometer, amplifier, SW SPURT with an added oscilloscope) in order to determine impact intensity at the moment when an object hits the material.

In the basic determination of impact attenuation, it is possible to use these values of impact amplitude with direct values of attenuation intensity in Volts, using the so-called rule of three, in order to determine the required recalculated value in percentage for the "passes" energy of the object falling through the damping mass.

100 % . . . . . . . . 5V (max. 10V)
x % . . . . . . . . 0.50V

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Figure 25. a, b, c, d – The height of the fall of the object is 35 cm,
the mass of the object is 0.15 kg (150 g). Total workplace with added oscilloscope

The ratio is then x = 10 %, i.e. max. approximatively x = 20 %. If the damping is 100 % and 10 % (or max. 20 %) of the impact energy of the falling object “passing” through the pad, then this corresponds to an impact damping of 90 % or 80 %.

Based on the experimenters’ personal experience, it was clear that the damping foam, in the case of strike motion actions, does not meet the said damping. For this reason, another measurement was performed in the form of a standardized strike with a hammer weighing 0.5 kg from the same height with and without a covering surface with an accelerometer.

The measurement brought similar results. In the last step, the thickness of the damping foam was measured at successive loads of 100, 200, 300, 400 and 500 Newtons.

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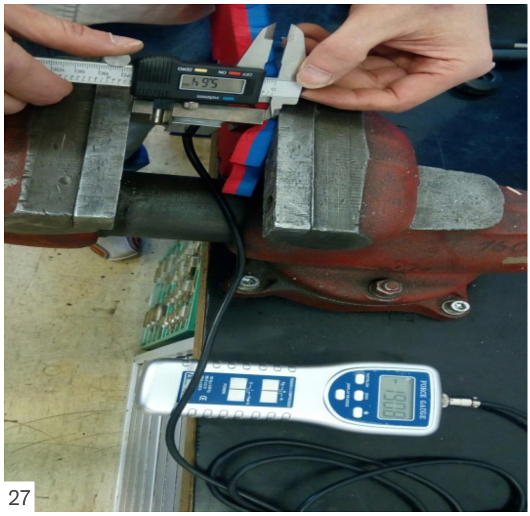


Figure 26. Measurement using a striking object weighing 0.5 kg
Figure 27. Deformation of foam using a load cell

The results of measuring dynamic and impact attenuation of foam bring up a number of issues, regarding especially impact attenuation. In the commercial sphere with a focus on damping pads for sports fields, impact attenuation is measured by various methods. Results of product attenuation can also be interpreted so as to present them as attractive for the market. In other words, attenuation values are not obtained by testing on “real” individuals, so the results can only be an estimate of consequences, for example, in relation to the tolerance of brain tissue to overload due to acceleration.

Foam deformation during compression indicated that impact attenuation of foam measured occurs up to a force limit of approximately 500 N. At this limit, foam thickness is below 1 mm and its attenuation is negligible in theoretical estimation. This fact is confirmed by experience from common practice: when tens of kilograms of an athlete’s body weight act on pads at a certain acceleration, foam deformations occur, and damping limits are reached. Martial athletes, who often perform movement actions like throw-overs and other whole body falls on pads (typically judo), usually use non-standard, special materials with a disproportionately higher dampening ability. Therefore, suitable conditions for training area equipment should also be considered for teaching self-defence systems.

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Table 4. Results for the red and the blue parts of the foam

| Foam side | (N) | (mm) | Blue side | Red side |
|---|---|---|---|---|
| Red | 100 | 9.4 | 6 | 3.4 |
| | 200 | 6.3 | 3.9 | 2.4 |
| | 300 | 4.5 | 3 | 1.5 |
| | 500 | 3.1 | | |
| Blue | 100 | 9.1 | 4 | 5.1 |
| | 200 | 5.7 | 2.5 | 3.2 |
| | 300 | 3.8 | 2.2 | 1.6 |
| | 500 | 2.1 | | |

With the support of measurements performed, the values for dynamic and impact attenuation of boards used were proposed: the value of dynamic attenuation was set to 20 % and the value of impact attenuation to 500 N. These conclusions must be extended by other measurements, especially for impact attenuation. It can be assumed that foam is likely to reach non-linear damping values up to a moment of compression force of approximately 500 Newtons. It is not known, however, how force in foam is damped in individual action vectors.

### 2.1.3 Strength and Speed of Upper Limb Impact in Martial Sports

There are large numbers of variants of movement actions like strikes and kicks which both students may encounter in self-defence courses and combat athletes in training and competitions. In particular, individual types of strikes differ from each other in their tactical variability, but also in their effectiveness in interacting with the human body. A clear classification of individual types of strikes for teaching purposes and also a comparison of strikes between each other can be useful especially for tactical coaches of self-defence systems and martial sports. These can get important information from the results regarding effects that physical actions have in relation to possible risks of injury.

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The study entitled “Strength and Speed of Upper Limb Impact in Martial Sports: Systematic Research and Meta Analysis” [7] aims to summarize and compare mechanical consequences of different types of upper limb strikes between different disciplines of combat systems: the system of martial sports, the system of martial arts and the system of self-defence. Based on a key search formula, approximately 2,000 studies have been identified in selected scientific databases, from which 71 target studies have been segregated by detailed filtering with the aim to describe strength and speed values as two main parameters needed to win a combat competition, but also to describe risks associated to injuries of combat athletes. Strike actions must be evaluated in the context of specific combat systems. These have, today, a significant place among human activities; they include martial arts, self-defence systems and martial sports [8,31]. Athletes in combat competitions compete in a variety of movement areas, including changes in the opponent’s distance, ability to stabilize posture, or a combination of attack and defence. A closer evaluation of sports combat systems must always be based on specific rules for combat competitions. Where upper limb strikes are allowed, head hits clearly prevail and score points in favour of victory in most martial sports due to the possibility of injuring opponents, reducing opponents’ cognitive functions or improving athletes’ own tactical position. [20]. For this reason, many movement combinations are aimed at the head in order to hit it effectively [114]. Athletes in full contact disciplines prefer fast and strong strikes, kicks and blocks [117, 128], where the head and face were evaluated as the areas with the highest frequency of injuries during MMA competitions [77]. The same conditions apply to the area of the self-defence system, where most self-defence techniques in their first attack movement phase are aimed at the attacker’s head. However, in most cases, self-defence systems do not contain competitive forms where strike effects could be measured and quantified. For this reason, conclusions and knowledge from the martial sports environment are valuable because physical actions can be tested with full commitment and almost no limit. Strikes are even more frequent than kicks in kickboxing and karate competitions (24 % kicks versus 76 % strikes) and clearly preferred for offensive combinations [93, 63]. In addition, they are relatively simple to perform and provide a great effect without enormous energy from the attacking athlete [43]. Compared to other combat actions, such as “knockdowns”, shoulder throws and others, strikes can be relatively well mastered due to their kinesiological and reflex bases, where the trajectory of upper limb strikes corresponds to functional tasks based on their fundamental movement

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Figure 28. Oi cuki: strike with high impulse potential

patterns [72, 5]. Other positive aspects of strikes are their high speed and execution variability, which causes an increase in tactical capabilities of fighting athletes. As a result, force impulse is considered to be the product of force acting over a certain (short) time; it is equal to linear momentum change and represents energy transfer between attackers and opponents:

$$\int_{t0}^{t1} Fdt = m \cdot \Delta v$$

Impact quantification and effectiveness is therefore usually based on measurements of inverse dynamics, impact velocity or a combination of both. Impact might be understood as the whole force impulse over the time of force exposure or as impact force acting from initial force application to the time of Fmax [120]. However, monitored parameters described in this study, namely Fmean and Fmax, represent two approaches to impulse.

A closer look at strikes and their potential in relation to injuries shows that there are a large number of strike tactical solutions which include not only strike surfaces but also impact surfaces. Strikes can be executed with different parts of the upper limb, like a clenched fist, palm or elbow or other parts of the upper limb and can act upon various impact zones.

This variability of strikes has become important both in modern self-defence systems and in MMA system combat competitions; the latter is described as the “decathlon” of martial sports with its own specific culture.

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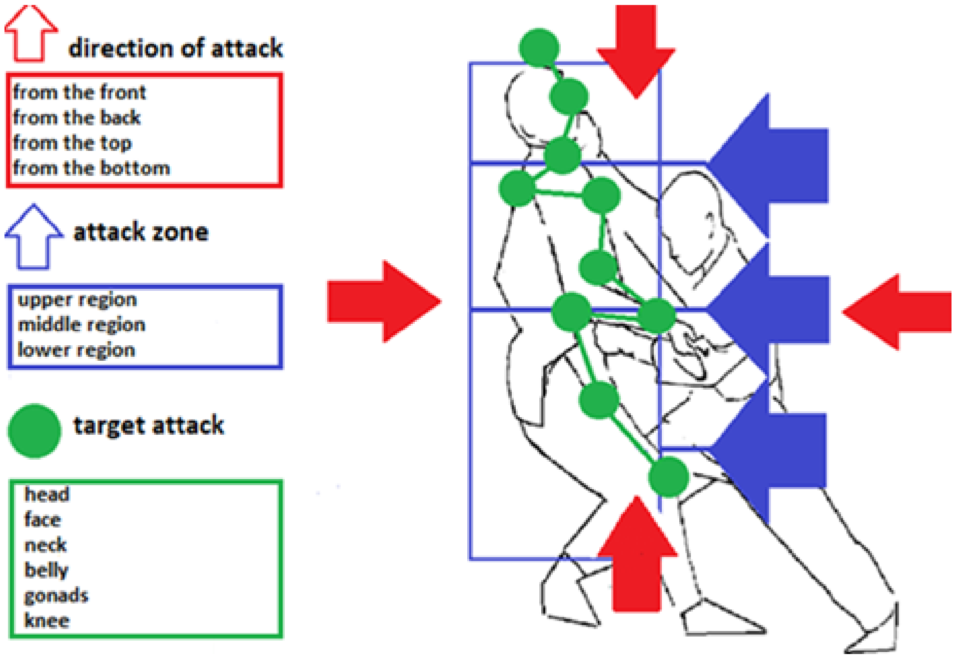


Figure 29. Strike and impact surfaces; strike directions

Figure 30. a, b, c – spinning back fist for left rotation

MMA athletes focus on specialized types of strikes that have a high tactical and impact potential, such as the "spinning back fist" and the "superman punch".

As there are new trends in individual preferences and a high variability of strike types, it is useful to clarify and compare different strike types of various combat systems between each other according to the strike trajectory, striking area, type of stance, hand rotation and hand preference (Table 5).

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Table 5. Characteristics of the strikes by the upper limb used in selected studies

| **Name of system** | | **Trajectory** | |
|---|---|---|---|
| | Straight | From side | From below |
| Boxing | Direct punch | Side punch | Low punch |
| Karate | Gyaku Zuki | | |
| | Oi Zuki | | |
| | Kizame Zuki | | |
| | Jun Zuki | | |
| | Tate Zuki | | |
| Kung Fu | Kung Fu punch | | |
| | | **Striking area** | |
| | Clenched fist (metacarpus) | Open palm (carpus) | |
| Boxing | Direct punch | | |
| | Side punch | | |
| | Low punch | | |
| Karate | Gyaku Zuki | | |
| | Oi Zuki | | |
| | Kizame Zuki | | |
| | Jun Zuki | | |
| | Tate Zuki | | |
| Kung Fu | Kung Fu punch | Palm strike | |
| | | **Type of stance** | |
| | a crossing of the hands and legs | no “crossing” of the hands and legs | |
| Boxing | Reverse punch | Straight punch | |
| Karate | Gyaku Zuki | Oi Zuki | |
| | | Jun Zuki | |
| | | **Hand rotation** | |
| | Before impact, the fist rotation up | Partial rotation | Without rotation |
| Boxing | Direct punch | Side punch | |
| | | Low punch | |
| Karate | Gyaku Zuki | Tate Zuki | |


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| | | | |
|---|---|---|---|
| | Oi Zuki | | |
| | Kizame Zuki | | |
| | Jun Zuki | | |
| Kung Fu | Kung Fu punch | | Palm strike |
| **Hand preference** | | | |
| | Front hand | Rear hand | |
| | Main hand<br>The jab | The cross | |

Straight punch term was unified from different synonyms like “direct”, “punch”, “direct punch”, and “blow”.
Side punch term was unified from different synonyms like “hook”, “arc strike”.
Low punch term was unified from different synonyms like “uppercut”, “upward punch”.
Front hand term was unified from different synonyms like “main hand”, “the jab”.
Rear hand term was unified from “The cross”.
(Beranek et al, 2020)

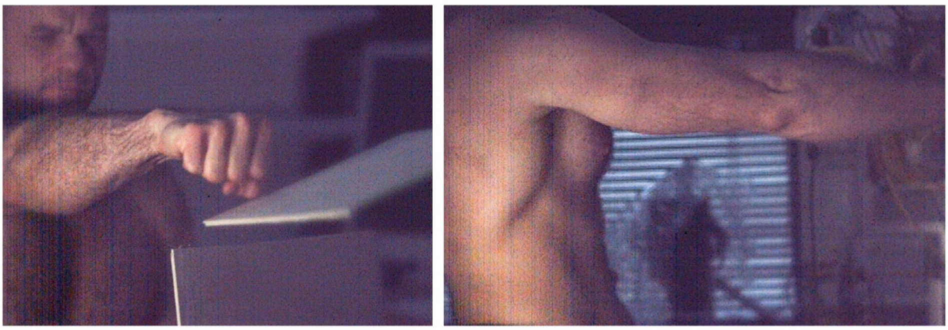

Figure 31. a, b – strikes are designed for maximum speed and force upon impact (shot from a high-speed camera during a measurement)

Biomechanical construction of strike actions applies to all strike types. The length of the hand movement is key, as well as the properties of impact surfaces [22], together with the type of stance that allows the hips to rotate [114] and affects stability during a strike [64]. The biggest differences between individual strike actions are in karate, where the main movement pattern for a direct strike is the same for gyaku-zuki, oi-zuki, kizami-zuki, jun-zuki and tate-zuki (Table 5).

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Figure 32. oi-zuki


Figure 33. tate-zuki


Figure 34. kizame-zuki

The movement is performed with the whole arm in a straight line and the striking surface is formed by a clenched fist. The movement of the hand starts close to the side; the back of the hand points downwards. Shortly before impact, the fist undergoes pronation, in contrast to tate-zuki, where there is only partial rotation.

Kizame-zuki is the same strike with added extension in the shoulders and hips.

Depending on the type of stance used, it is possible to distinguish a reverse punch (gyaku-zuki), with the contralateral position of the hand and foot, and a straight punch (oi-zuki) with the ipsilateral position of the hand and foot.

In the case of similarities, a direct boxing punch may be the same as a reverse punch in karate (65). In a kung fu strike, the movement is led with the hands close to the face with elbows drawn in so as to protect the ribs (22). The side punch and low punch are typical for boxing and have an arc trajectory of movement. Side punches come from the side and low punches come from lower down. For a palm strike, the striking surface is formed by the open palm of the hand.


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Figure 35. gyaku-zuki

Figure 36. oi-zuki

Overall, each type of strike provides a different spatial stance and provides different tactical conditions for attacking an opponent or blocking a strike during a collision. In this context, each type of strike has its significance. Impact is determined by an athlete's decision to make a movement; initiating a striking action allows for higher speed and impact than reacting to a striking action [57].

In the framework of the study [7], it was not possible to provide information reporting measurement results of short-distance movement actions – elbow strikes. The reason may be the fact that all but three studies [22, 89, 90] were aimed at sports systems where elbow strikes are not allowed, with a few exceptions. Only a few martial sports allow for the use of elbow strikes in their rules: the Thai boxing system [73] and the MMA system [85]. Elbow strikes are important technical and tactical elements, especially in the MMA system, where athletes can develop high efficiency with the upper limb with the help of the small and hard edge of the humerus – the olecranon. Athletes can fight in both stance and non-stance combats within the MMA system, as well as apply elbow strikes in a stance and also on the ground. They often take advantage of this rule-given option because a high impact force in the area of the facial bones can cause a knockout or a tactical injury to the opponent's face. Such an injury in the form of tissue rupture in the forehead or superciliary arches does not primarily exclude opponents from the fight, but blood flowing into the eye area impairs their concentration

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and orientation in the space. Referees can also interrupt a match in order to briefly check the injury; at that moment, opponents thus have time to regain their strength. If there is a strong flow of blood to an eye, medical supervision may end the match due to serious damage to the eye. Any visible injury also brings with it a certain stigma, as it confirms a successful action of the dominant athlete who caused the injury. These are all tactical reasons that can promote elbow strike movement actions both in combat competitions and real self-defense environments. Some studies also compare direct strikes performed by the dominant or the non-dominant hand; a strike by the dominant hand reaches higher maximum forces and higher speeds (89, 112). Strike strength can also be determined by other factors, such as experience. Experts achieve higher Fmean, Fmax and strike speeds than beginners (27, 90, 40, 108). Although athletes can use a wide range of strikes, they do not have many opportunities to compare the effectiveness of different strikes between each other due to frequent limitations of rules according to the specifics of each martial sport – except MMA competitions, where athletes can use any strike at its full intensity (85). Therefore, the aim of the study (7) was to find out which types of strikes are the most effective for winning a competition, and whether their impact force is the highest, as we expected (111). Elite boxers demonstrated higher impact forces represented by average force (Fmean) and maximum force (Fmax) than beginners, and boxing match winners had a higher Fmean than their losing opponents (99). Fmean has also been identified as one of the parameters that can determine victory in a match (20). Fmean was even more important for success in combat competitions than the strike speed and accuracy (79, 99, 111). On the other hand, a strike by the upper limb can be performed at a speed that is higher than an opponent's defensive reaction (0.2–0.4s) (124); the striking action speed can then decide the victory. Considering the information that hand speed and impact characteristics correlate (83), the hand speed, Fmean and Fmax can be considered potential parameters determining the result of a match. However, current literature lacks evidence and comparison of different types of strike in terms of inverse dynamics or strike speed. Previous studies examined Fmax, Fmean and hand speed and acceleration during strikes which were selected within different sporting disciplines (40, 53, 27, 122, 89). Some studies compared different types of kicks in taekwondo, karate or kickboxing (56, 51, 97, 26, 98), and other studies compared kick biomechanics with upper limb strikes (124, 92). So far, however, there has been no comparison of the types of strikes between each other. For this reason, one of the interesting outputs of the study is a portfolio of strikes

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according to selected mechanical properties, which may indicate their potential for combat competitions or self-defence and associated risks of injury. Which type of strike reaches the highest impact forces and speeds in the target? (Table 6 in attachment)

The studies included made it possible to compare a total of ten (10) types of striking action within the martial sports system (boxing, karate and taekwondo) and the martial arts system (kung fu). Two types of impact surfaces were associated with striking actions: the area of the metacarpals and phalanges in a clenched fist and the area of the palm including the palm edge of the little finger. Strikes can be further divided according to movement trajectory into straight direction, direction from the side and direction from below. The studies reported physical values Fmax and Fmean (N), acceleration (m/s/s), gravitational acceleration (g) and mass (kg), where measuring instruments were assembled from accelerometers [66, 71, 26], high-speed cameras [65, 20, 112, 90] and a combination of both [122, 22], force boards with high-speed cameras [27, 114] or tensometers with high-speed cameras [40, 91, 64]. Therefore, we might conclude that the measurement of strikes lacks unification in terms of the methodology and equipment used, e.g. by using a dummy [28].

Of a total of 28 studies, 16 studies that did not include comparable quantitative values were excluded for quantitative synthesis. 12 studies [40, 22, 122, 114, 78, 64, 26, 20, 99, 89, 90, 91] which also reported standard deviations were included in the statistical analysis. The studies were performed using participants with professional level of experience and three studies were performed using participants with a mixed level of experience [90, 71, 27].

A one-way ANOVA test was used for statistical data processing; it showed differences between the values of average forces in different studies and different types of strikes. A post hoc test showed that kung fu strikes showed the lowest values compared to other types of strikes. In contrast, direct strikes showed the highest values. The average force of all strikes was 1,348 N and the average speed of strikes was 8.8 m/s.

The highest frequency of reports used direct strike action movements in the style of karate (oi-zuki, gyaku-zuki, tate-zuki) and in the style of boxing. Direct strikes had the highest values of the average force Fmean (3.42 kN) in the study of Walilko et al. (2005) and also the highest value

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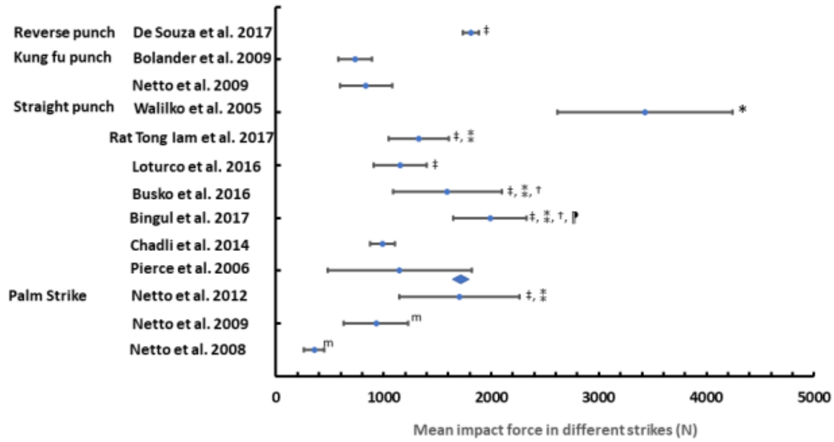


Figure 37. Average force of strikes (Beranek et al, 2020)

**Figure** Mean impact force reported for different strikes
Legend: m = study with mixed experience values, ‡ larger value than both kung fu punches using Tukey post hoc test, * larger than all other punch values using Tukey post hoc test, ⁑ larger than Chadli et al. (2014) punch using Tukey post hoc test, † larger than Loturco (2016) punch using Tukey post hoc test, ⁋ larger than straight punch using Busko et al. (2016) and Pierce et al. (2006) Tukey post hoc test, the diamond box represents the weighted mean for the straight punch.

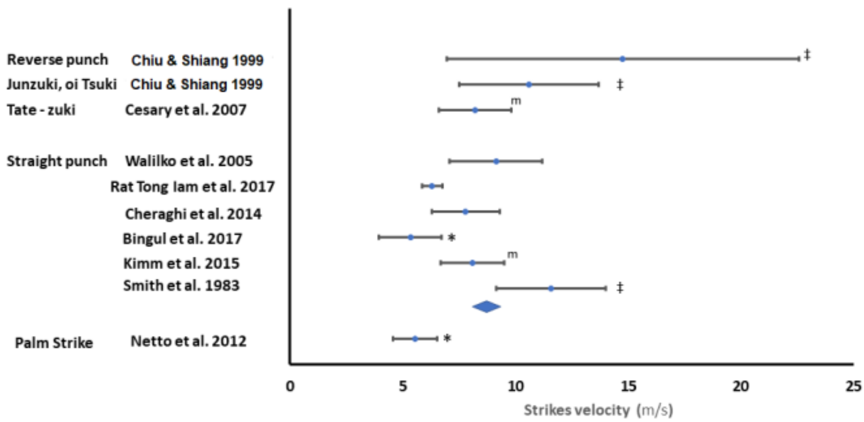


Figure 38. Average speed of strikes (Beranek et al, 2020)

**Figure** Mean velocities reported during different strikes
Legend: m = study with mixed experience values, ‡ larger punch value than other authors without this mark using Tukey post hoc test, * lower than all other punch values without this mark using Tukey post hoc test, the diamond box represents the weighted mean for the straight punch.

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of the maximum force Fmax (4741 N). However, the strike speeds did not differ from other strikes.

Direct strikes not only show the highest values of force, but are also the most frequent type of strike in martial sports such as kickboxing, karate and MMA [93, 43, 39, 126, 53]. The same conclusions can be expected for self-defence systems, where only dominant movement actions are required with regard to the need to succeed in real conflicts. Although direct strikes are key components of martial sports [114] and, according to the conclusions of some studies, are related to winning a combat competition, there are other results of studies. Measurements made for boxing [37] showed that punches from the side (boxing hooks) distinguished winners from losers during semifinals and finals of boxing championships.

In addition, punches from the side have the potential for high values of rotational acceleration of the head, causing brain trauma in all its areas [29]. Based on these research discrepancies, it seems advantageous to independently process specifics of various strikes, measurement approaches, average strike speeds and forces, vectors and their relationship to injuries within individual combat disciplines. Strikes with a certain value of Fmean or Fmax have the potential for injury risks, which some authors evaluate in connection with the boxing and the taekwondo systems [122, 113]. Risks of injury are even more likely when strikes are aimed at an athlete's face, where biomechanical tolerance of different regions of the facial bones has been reported [1]: os nasale has the lowest tolerance (0.5 kN), followed by maxilla (0.7–1.5 kN), os zygomaticum (1.0 kN), mandibula (1.4 kN), lateral region of cranium (2.0–3.6 kN), temporoparietal region (2.5–5.2 kN), frontal region (4.0–6.2 kN) and occipital region (12.5 kN). When comparing the highest Fmean values for direct strikes with the contact force required for a bone fracture, fractures can be caused in six regions of the skull. When comparing Fmax, fractures can be caused in seven regions of the skull. Overall, four studies reported values that approached or exceeded the tolerance of most facial bones (5kN) [3, 42, 122, 99]. On the other hand, high impact forces of strikes can also cause injuries to attackers, who initiate movement actions [74, 109], on the basis of Newton's third law.

This study had several limitations. First, the analysis did not include average force and speed of strikes in relation to body mass. However, according to some studies, body mass is not a determinant of reactive force [99, 90] or

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strike speed (122). Neither did original studies (Table 6) report such values. Although the body mass plays an important role in energy production and reactive force in the course of kicking techniques (97, 103), this does not apply in the same way to upper limb strikes (99, 90), where the level of experience (36) and an athlete's stance (20) are key variables.

MMA athletes, self-defence coaches and tactical coaches can expect direct strikes and cross strikes to reach high speeds (over 10 m/s) and high impact forces. However, this also means that there can be significant risks of injury, both in combat competition and martial sports training or self-defence courses. Study "Upper Limb Strikes Reactive Forces in Mix Martial Art Athletes during Ground and Pound Tactics" (11) pointed out, that straight punches, palm strikes and elbow strikes in strategy ground and pound inside MMA system also can cause high impact potential and they should also be considered for high injury risk. For this type of punch (ground striking) can be expect a high Fpeak (2900–4100 N) and palm and elbow strikes also provided extreme reactive maximum peak forces (for men, 13 kN), which have a high probability of causing head injury. The elbow strike has the highest potential to reach extreme impact values and fracture skull bones. In this study, the dominance of palm strikes and elbow strikes was also confirmed by the conclusions of probability results, where a significantly higher probability of reaching a peak force of 5.1 kN occurred with elbow strikes and palm strikes than with straight punches. In the overall results across genders, only 10.2 % of strikes reached the level of 5.1 kN for a straight punch with a clenched fist as opposed to elbow (26.2 %) and palm (27.4 %) strikes. When considering all participants, there were 10.2 %, 26.2 %, and 27.4 % probabilities of exceeding the selected force threshold with the straight punch, elbow strike and palm strikes, respectively. These are the probabilities that most of the cranial bones would suffer from serious injuries. When stratifying the data according to gender, these probabilities increased to 18.3 %, 36.3 %, and 36.1 % with straight punches, elbow strikes and palm strikes, respectively, in the male group. In the female group, these percentages were much lower, with 0.1 %, 2.5 %, and 6.0 % with straight punches, elbow strikes and palm strikes, respectively (11) (Figure 39, 40). Methodological tools aimed at minimizing risks of injury in stance and non stance strikes training are crucial.

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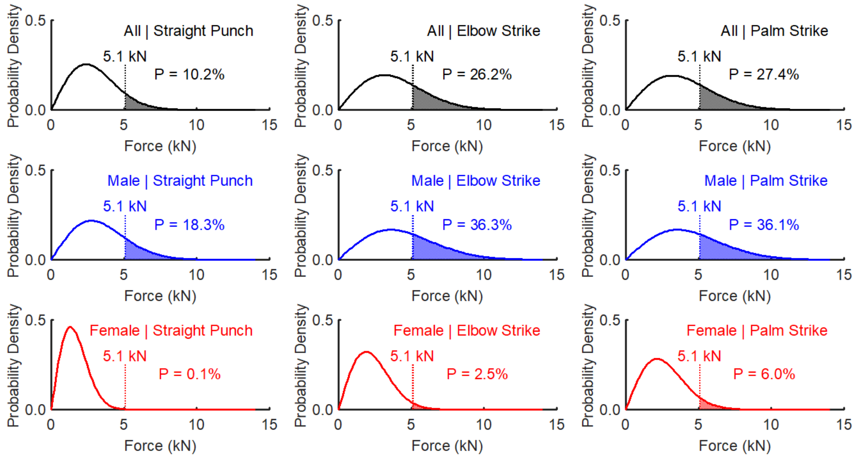


Figure 39. Probability of exceeding the 5.1 kN threshold force. The blue color–Male, the red color-Female.

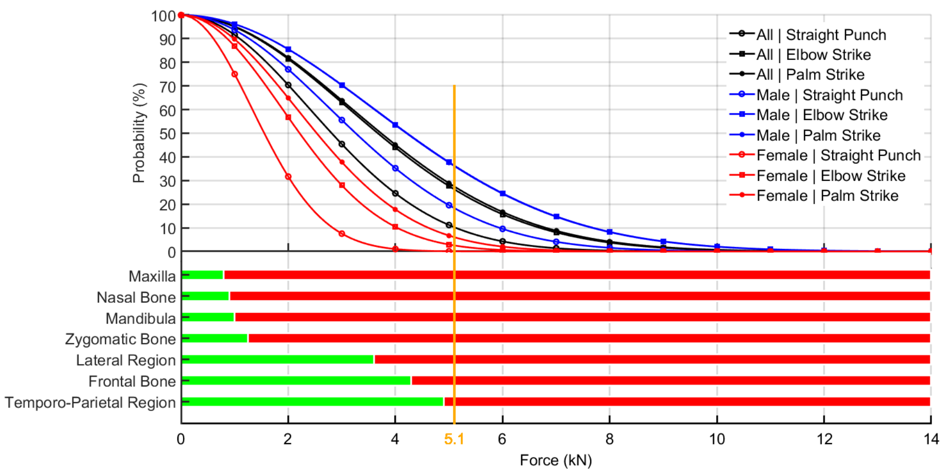


Figure 40. Probability of different strikes to exceed the 5.1 kN and bone tolerance. Green color–limits of allowed average load tolerance of bone fracture. Red color–over the limit of allowed average load tolerance of bone fracture.


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## 2.2 Methodological Tools for Injury Prevention – Length

Length (**L**) is a basic physical variable that expresses the mutual position and spatiality of objects in space. Its basic unit is the metre (m). In the self-defence system, it is especially important for the description of the space in which some movement takes place. Length most often describes the value of sports performance, but in self-defence, it is crucial especially for the description of correct tactical distance, for the vectors of strikes and kicks to the upper, middle and lower impact range. It can be assumed that impact force will increase with the length of the strike path, which promotes greater limb acceleration. This is confirmed by the results of studies (55, 90, 22) where long-range impact forces achieved were significantly greater than short-distance impact forces. As force increases with increasing distance, instructors must manage distances during beginners' training so as to minimize potential risks.

### 2.2.1 Smart Impact Zones

Beginners make several mistakes in their simulations of attacking their buddy in pairs. Most often, these include a disproportionate acceleration of the offensive movement action, the so-called "exaggerated strike". This means that a uke cannot control the path of the offensive action over the entire range of movement and adapt to the tori's defensive potential (reaction capabilities). Potential unblocked impacts in a tori's body should be considered a natural part of the training process, which must, to some extent, approach the environment of real conflicts. However, the frequency and consequences of this error must be corrected, for example, by using protective equipment (protection of the head, teeth, hands, feet, gonads, etc.). In training without protective aids, the frequency of injuries can be reduced by identifying the riskiest movement patterns and involving selected preventive tools.

#### 2.2.1.1 Smart Impact Zones for Direct Upper Limb Strikes on the Upper Zone

Beginners, in their attacks, are often subject to their subconscious mind, which does not want to cause injury and pain to defenders. For this reason, they often carry out so-called "false" attacks, where clenched fists move

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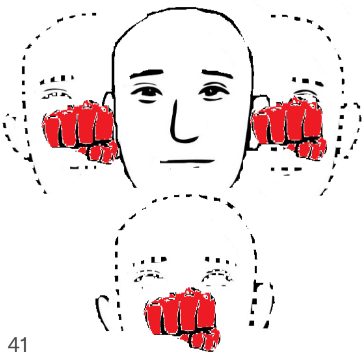

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42

Figure 41. Attackers tend to apply false attacks that can collide with defenders' evasive maneuvers (to the left or to the right of the impact zone or below the impact zone).
Figure 42. The direction of attack on the frontal bone area of the skull

the impact area to the right or left next to the face. Paradoxically, these can cause injuries too just because defenders often make an evasive manoeuvre to the side for fear of being hit, and the facial part of their head may collide with this false attack. A uke can also change their "false attack" from a horizontal direction to a vertical direction below the level of the face to the area of the pectoral muscles, so as to avoid a potential threat to their buddy's head. However, the buddy can suddenly lower the stance due to an instinctive reaction to the strike and the impact surface thus moves again to the bones of the facial part of the skull.

The only safe trajectory for directing a strike to the face is towards the frontal bone (os frontal). The solid composite of this part of the skull poses a minimal risk of injury because not all potential attack and defence mistakes end up hitting easily vulnerable tissues of the lower jaw, upper jaw, nose, orbit, etc., with the hand. Also, beginners do not jump during training as jumping can expose them to collisions with strikes of this trajectory.

### 2.2.1.2 Smart Impact Zones for Lower Limb Kicks to the Bottom Zone

Kicking methodology in self-defence systems favours low impact zones, such as a lower limb pendulum kick on the genitals with the impact

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Figure 43. By partially fixing their foot on the ground, defenders perform a kick along an incomplete path of movement without limiting the acceleration of the limb and related movement patterns.

surface of the instep or shin of the attacker or a kick with the knee. The target impact zone includes muscles of the thighs, the groin (gonads), the abdomen or the head. Reported impact forces of the lower limb are higher than impact forces of the upper limb (123, 92) and unwanted impacts can be associated with serious consequences. Lower limb attacks also place higher demands on the stability of attackers and, to a greater extent, support the emergence of tense training situations with a higher probability of mistakes. On the other hand, training actions for kicks must be conducted with a certain speed, dynamics and intensity, as their force potential in real conflicts represents a chance for a defender to survive. For this reason, we must not neglect correct implementation of the technique, where dynamics is one of the key parameters. The presence of adequate training equipment (paws, leg protectors, protection of the gonads) provides an opportunity to apply kicks in the entire movement range and with maximum intensity. In training without paws, it is necessary to adjust the technique implementation.

In the pendulum and knee kick techniques, defenders leave part of the sole in contact with the ground during the dynamic phase of the kick. They do not have to regulate any other parts of the movement pattern, and yet maximally protect attackers from potential injuries. The striking surface of the foot performs a very short path of movement compared to movements

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in full deployment; still, important habits, such as a stable stance, parallel cooperation of the upper limbs and dynamic activation of the lower limb are maintained. With the help of this modification, which shortens the path of the moving limb, it is also possible to more effectively master the tactics of kicks with a high frequency of repetition. The position of the foot can be changed arbitrarily and is not limited by counter-movements of attackers, as defenders can position the contact of their foot with the ground according to current needs.

## 2.3 Methodological Tools for Injury Prevention – Physical Variable of Mass

Mass (**m**), in the self-defence system, represents a variable that contributes to the degree of effort that defenders must make when changing the movement state of the body or body components of attackers. Defenders always work with force through these movement state changes in interaction with attackers. Force (F) is a vector variable determined both by the magnitude, direction and position of its field of action. Newton's Second Law of Movement of Force is key for the self-defence system: F = m.a, where **m** is the body mass and **a** is the acceleration vector. Understanding how force arises is key to understanding risk mechanisms of strikes, kicks, telescopic baton techniques, etc. This is where injuries most often occur due to the contact of defenders' attacking limb or self-defence device with attackers' body tissue.

Studies show possible high maximum values of the impact force Fmax for upper limb punches in a straight line with a clenched fist: 3075 N (Beránek, 2017), 5358 N (Pierce et al., 2016), 4741 N (Walilko et al., 2005), 4236 N (Dyson et al., 2005) and 4096 N (Atha et al., 1985). Movement actions performed by the lower limb usually reach twice the values of strike impact forces. Strikes with a telescopic baton can reach values of up to 10 kN (Beránek, 2017). A number of physical aspects are involved in the mechanism of impact-induced injuries. These are the mass (m) of the moving limb or object, the acceleration (a) of this limb or object and also the properties of the striking and the impact surfaces. Equally important is the factor of the biomechanical tolerance of individual tissues of the human body to load, as well as a number of other variables.

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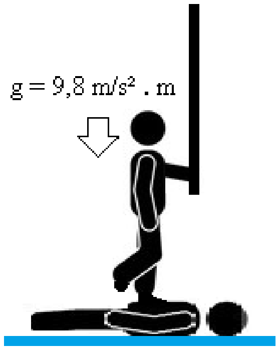


Figure 44. Practical Striking Test A

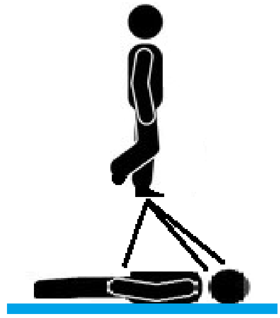

Figure 45. Practical Striking Test B

### 2.3.1 Practical Striking Test

The aim is to explain to students the risks associated with the destructive effects of strikes and kicks on human tissue. First of all, it is important to provide lay people with numerical values of force, which express a certain degree of severity in relation to consequences for a living organism. It is appropriate to use the physical unit of force Newton (N) in order to create an equivalent value of static force (mass) in units of kilograms (kg). The physical unit of mass is easier for lay people to understand because they can think of it as the weight of their body, which they know well. Beránek et al., 2020 reports an average force value for a direct strike of 3427 N, i.e. approximately 349.33 kg. The highest maximum reported value of a direct strike reaches up to 5358 N and, after dividing it by the value of the gravitational acceleration of the Earth (9.81 m / s2), it represents the value of 546.18 kg. The values of the static force equivalent recalculated in this way are prepared for a practical striking test, which consists of parts A, B and C.

The test takes place as a pair job. The uke assumes a supine position, on their back, on a soft surface. The tori is in a standing stance and, with the support of at least one upper limb upon a fixed point, loads, with the entire sole, the centre of the uke’s abdominal muscles. The uke tries to accept the static simulation of the kick for a few seconds with the help of activating the abdominal muscles. Partners in pairs take turns and recalculate the force of the strike which they performed as attackers, according to their total body mass. Despite the fact that this first phase is already a limit for many

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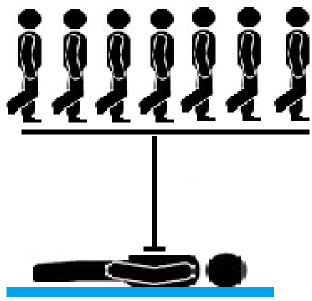


Figure 46. Practical Striking Test C

students, the striking force, assuming an average student's weight to be 80 kg, is only 30 % of the average value of force measured for a direct strike.

The test also takes place as a mental experiment in the form of a discussion with students: the uke can load the areas of the nose, larynx and gonads in the same way. In such a case, irreversible damage would then occur to these tissues due to their low value of load tolerance. The most common injury that the lay population knows in connection with a strike applied to the head is a nose injury. Nasal bone fracture is limited by loads from 0.3 kN (table 7 in attachment) to 0.5 kN (1)

This represents a static force equivalent of approximately 50 kg. This means that helpers exceeding 50 kg of weight can simulate the static equivalent of force with a potential effect of a nasal bone fracture.

A demonstration of a maximum impact force of 5358 N for the boxing system (Pierce et al.) can be simulated with seven helpers.

Values of impact forces of strikes in martial sports reach high values and often affect sensitive areas of athletes' heads. Head and hand protection and other types of protectors mitigate the effects of such actions, but do not completely minimize injury risks. The consequences of strikes on the health of combat athletes are real, frequent and are reported in a number of studies. People inexperienced in sport often suffer a lack of information on how easy the mechanism of an injury is. First of all, it is important

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for students to be able to imagine such risks and think about them. This can be achieved in discussions with their teachers or trainers, who can acquaint students and athletes with the latest knowledge.

### 2.3.2 The "Semaphore" Diagram Used for Categorizing Striking and Impact Surfaces

The aim is to enable students to safely practice strikes using a suitable combination of striking and impact surfaces with an adequate level of experience. Effects of strikes, kicks or striking self-defence means (telescopic batons, improvised weapons, etc.) depend, among other things, on the properties of striking surfaces in combination with the properties of impact surfaces. If the pressure (p) is the ratio of force applied in a perpendicular direction to a surface (S) (**p = F / S)**, the final effect of the impact by the limb at the target can be graded through a suitable selection of the striking and impact surfaces. In the first step, the semaphore divides the striking and impact surfaces into soft and hard ones. The striking surface is the part of the surface of, mainly, the upper or lower limb or the skull that come into contact with body tissue upon impact. For example, a soft striking surface is an open palm strike. Hard striking surfaces are located on the articular ends of a clenched fist and on the bony protrusion of the humerus (olecranon), as well as on the articular ends of legs and knees. The impact surface is the part of the body surface which comes into contact with the striking surface. Soft impact surfaces include muscular parts of the human body (the abdomen, large muscles of the upper or lower limbs and the torso). Hard impact surfaces include bones of the skull, articular and bony parts of the upper or lower limbs and also the spine area.

Green field

Type of strike: strike with an open palm into the areas of pectoral muscles, abdominal muscles and muscles of the upper and lower limbs.
Output: students master basic tactical conditions for attacks – distance, stability, technique of strike or kick, in the role of both defender and attacker.

Yellow field

Type of strike: strike with an open palm into the areas of pectoral muscles using all impact areas.

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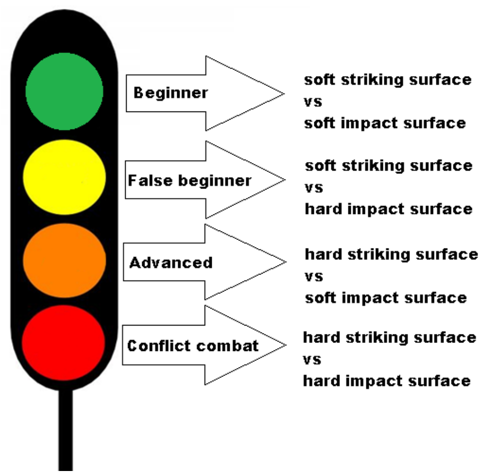


Figure 47. Categorizing Semaphore of striking and impact surfaces

Output: students master striking techniques for all impact areas.

Orange field
Type of strike: all striking techniques.
Output: students master techniques of all strikes on both soft and hard impact surfaces, but not the combination of hard striking surfaces on hard impact surfaces.

Red field
The training becomes a real simulation of sports combat with standard regulations in the form of protective aids and rules.

## 2.4 Methodological Tools for Injury Prevention – Time

The significance of length in self-defence is closely related to time (t), as attacks move in their orbits at a finite speed and acceleration. For defenders, reaction times are key; the minimum theoretical reaction time of a person to an attack is 0. sec[7], almost up to 0.4 sec, while the

[7] Minimum time for detecting the presence of a stimulus 0.05 sec, minimum time to select an adequate response 0.05 sec, minimum time to start movement 0.08. Altogether 0.18 sec as the minimum theoretical time for an opponent‘s reaction (Wasik, 2009).

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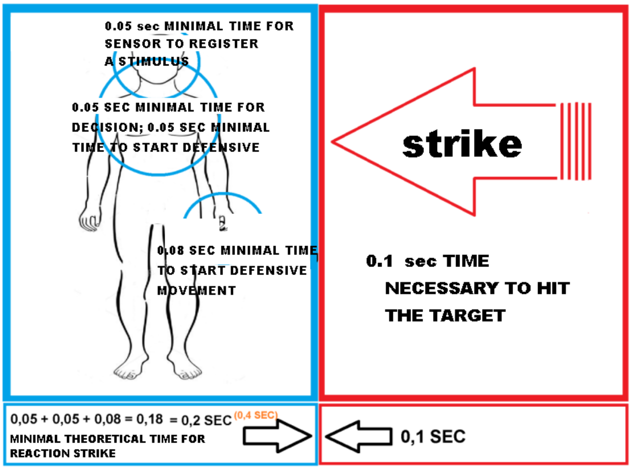


Figure 48. Diagram of the speed of defender and attacke' reactions
0.05 SEC ... MINIMAL TIME FOR SENSOR TO REGISTER A STIMULUS;
0.05 SEC ... MINIMAL TIME FOR DECISION;
0.08 SEC ... MINIMAL TIME TO START DEFENSIVE MOVEMENT;
0.05 + 0.05 + 0.08 = 0.18 = 0.2 SEC ... MINIMAL THEORETICAL TIME FOR REACTION STRIKE
0.1 SEC ... TIME NECESSARY TO HIT THE TARGET

time to hit/strike a target is only 0.1 sec [(124)]. This means that, in theory, it is not possible to avoid an impact by a mere reaction in the moment of surprise.

### 2.4.1 Reaction Times

Implemented results of reaction speed measurements further indicate that reaction times differ depending on receptors. The duration of tactile stimuli is about 0.15–0.14 s, auditory stimuli 0.16–0.15 s and visual stimuli 0.21–0.19 s [(33)]. Beginners usually choose disproportionately high attack speeds, to which defenders cannot respond due to limited reaction time of the central nervous system. In addition to injury risks, also erroneous fixations of self-defence technique occur, where unnecessarily high speed or acceleration does not allow for acquisition of all important phases of movement actions.

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Defenders, regardless of their technical skills, are not able to respond to stimuli immediately, but only after the reaction time has elapsed. Defensive maneuvers also consist of several movement actions, where cooperation of the upper and lower limbs is required in particular. This prolongs the reaction time. In order for students in pairs to start a successful simulated defence, they must have sufficient time for manoeuvre execution. Consequently, attacking action time should be longer than defending reaction time.

According to the formula **F = m. a,** both mass and acceleration contribute to the final force. Mass, both the total weight and the weight of specific segments of the human body (in this case, the attacker's own attacking upper limbs) cannot be influenced by students. However, they can regulate acceleration of their limbs. Maximum upper limb impact speeds were reported: 14$ms^{-1}$ (Halperin et al., 2017), 13.4 $ms^{-1}$ (Walilko et al., 2005.), 13 $ms^{-1}$ (Gianino et al., 2009.) and acceleration 296 $ms^{-2}$ (Chadli et al., 2014). In the first step, it is appropriate to explain physical units of speed to students by converting them from unit $ms^{-1}$ to unit km/h (1 m/s = 3.6 km/h). These are easily conceivable, for example, as the speed of a moving vehicle in road traffic. The highest reported speed of an upper limb strike (14$ms^{-1}$) thus represents the value of a moving car at a speed of 50.4 km/h. For example, the braking distance of an average car in good technical condition is 15 meters on a dry road at this speed; then the car hits a road's shoulder and only 20 % of pedestrians survive a collision with a car travelling at 50 km/h. Physical conditions of combat competitions and the environment of car accidents obviously differ, especially in the parameters of mass and contact surfaces. It is important for students to be able to imagine what speed actually is and what its consequences are.

### 2.4.2 Semaphore of Distances

The aim is to enable students to practice strikes safely by prolonging the total attack time using a required distance between partners. Beginners in a pair can also signal an attack verbally (Attacker: "Now I am going to attack you with my right hand.") or non-verbally (upon agreement, attacks are initiated from the side of a lower limb, for example, or attackers point to the attacking hand with a small rotary hand movement and so on).

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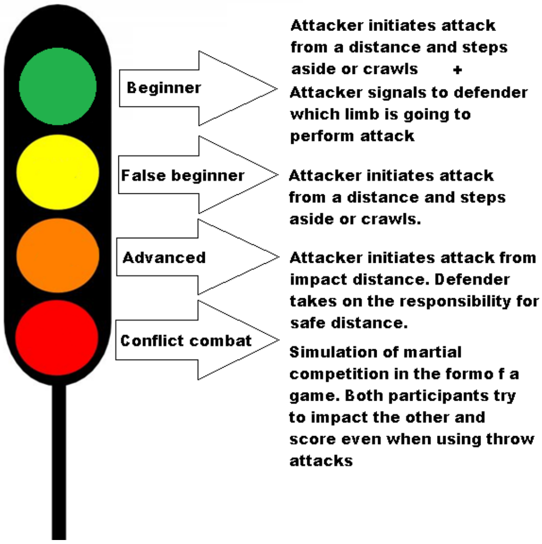


Figure 49. Semaphore of distances

Note:
Combat competition simulations, within given rules, choose movement actions that do not cause injuries to participants (e.g. "slapping game"). Otherwise participants are equipped with all necessary protectors of the teeth, head, hands and legs proven effective in martial sports competitions.

### 2.4.3 Semaphore of Speed

The aim is to enable students to safely practice strikes with individual speed control. Beginning defenders start self-defence reactions from a static form of attack. This means that after the impact of the attacking limb, the uke "freezes" before the target and leaves their limb in the "impact" extension. In this case, the tori has enough time to perform a cover, block or evasive maneuvers. Higher levels recommend a percentage speed ratio of the maximum possible attacker potential.

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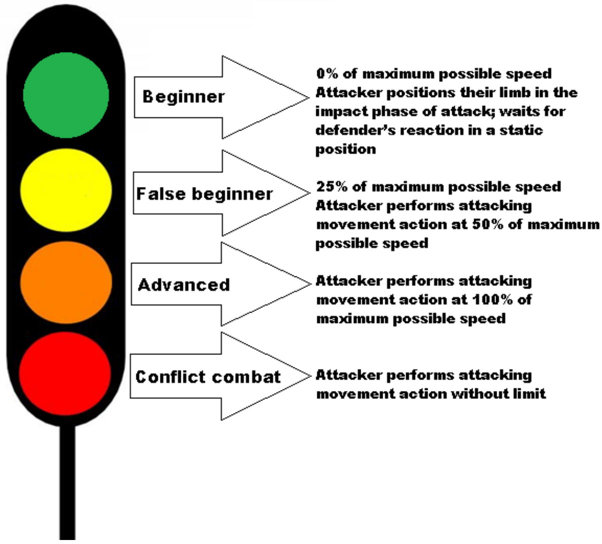


Figure 50. Semaphore of speed

### 2.4.4 Combining Multiple Tools into a Methodological Series

With regard to possible differences in initial physical and mental dispositions of students, it is necessary to set sufficient safety barriers. Beginners do not have basic sports habits and self-defence reactions. They often show unexpected sudden physical actions. They also tend to compare themselves with more advanced colleagues and have inappropriate goals in order to cope with others, for example with the help of strong and aggressive physical actions. Teachers must always evaluate the current potential of their students individually. The semaphore tools can create, in the form of combinations, measures that protect helpers at all levels. For example:

> *Beginning attackers perform attacks only with a soft striking surface on a soft impact surface, always initiate attacks with changing their stance and signal the attacking hand; at the moment of impact, they go into the static phase, which gives defenders necessary time for required movement actions. On the other hand, professionals, for example, training for a combat competition, choose any striking and impact surface and any distance, not limiting the intensity of their physical actions in any way.*

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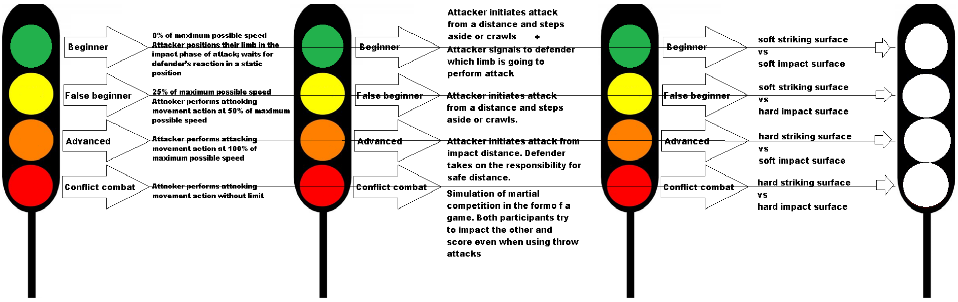


Figure 51. Combinations of semaphores

## 2.5 Guide to Safe Leverage

Leverage techniques form an essential part of the training methodology of self-defence and, especially in professional self-defence with a focus on security forces, play an important role, for example, in the form of handcuffing techniques. Leverage techniques work on the basis of simple mechanical properties of the bones and joints of the human body. Each joint has its natural range of motion, and if this range is exceeded, the joint reaches an unnatural position, which is very painful, and, in extreme cases, the joint and ligament can be injured. Leverages, especially of long bones, act on their torque articular joints, where a linear dependence applies: the longer the arm-acting force, the less force is required to produce a corresponding torque effect. It follows that leverages, especially those that work with long limb bones, are very effective even with a relatively small force applied at the end of a limb. The line between attackers' safe pain and irreversible destruction of their joint apparatus is very small. In addition, body segments where leverage effects can be used include not only the upper and lower limbs, but also the cervical spine, where possible consequences can be fatal [17]. Unfortunately, injury risks cannot be avoided by reducing the technique, i.e. without "levering" the opponent up to tolerable pain, because absence of feedback would impede defenders' technical progress. It is necessary to look for other ways of regulating course participants.

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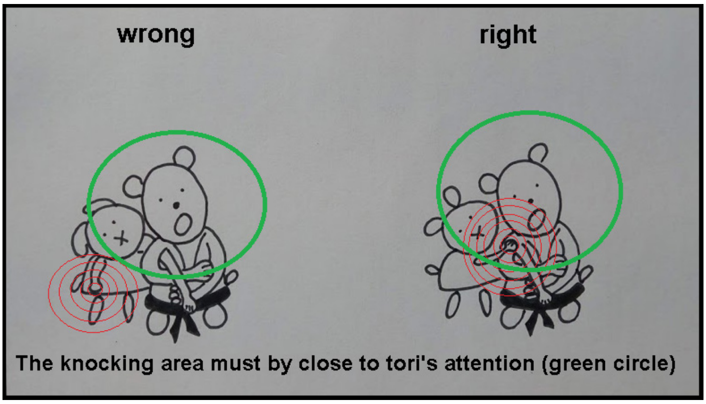


Figure 52. A teacher is demonstrating both the correct and the wrong variants, in the form of a game.

### 2.5.1 Technical Recommendations

**Tapping**

Tapping is an internationally recognized sports signal, typical of the judo system in particular. In the process of fighting, attackers signal, by tapping with their free upper limb, that they are giving up. Immediately after registering this signal, defenders must stop levering, strangling, choking, etc. From a methodological point of view, the tapping of the uke is, for the tori, a confirmation of correct execution of levering, strangling or choking techniques.

**Tapping Intensity**

Teachers demonstrate to students the principles of tapping in leverage techniques on the elbow with external rotation. Students test the intensity of tapping on themselves. The higher the intensity, the lower the risk of injury in the pair. Mistakes include faint, quiet, weak tapping, which may not be registered due to other sound stimuli in the training space.

**Tapping Place**

Teachers demonstrate to students the differences in tapping on the tori's body (the one who is levering) and on the uke's body (the one who is levered). Tapping on the tori's body is a guarantee that the tori will detect this signal. But when the uke taps on themself, they run the risk that the

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Figure 53. Teacher is demonstrating pinning the attacker on the ground with blocked limb mistake
Figure 54. Teacher is demonstrating pinning the attacker on the ground with blocked limb control.

tori will not notice. Tapping on oneself may be out of sight of the tori, and also the tapping sound may not be perceived.

**Blocked limb**
Professional self-defence techniques, especially those aimed at police work, favour the termination of self-defence actions by pinning the attacker on the ground. Defenders often use techniques of levering one upper limb of the attacker for subsequent deployment of handcuffs. Practical experience shows that during a maneuver with an attacker's body on the ground, the attacker's other upper limb, which is located under their own body, can be blocked.

Therefore, the tori must always have visual contact with both the uke's limbs at the end of the technique. The stabilization of this procedure serves not only to safely end training actions by tapping the hand, but also to check an attacker's hands for potential presence of a weapon.

### 2.5.2 Tachometer Tool

When using leverage, defenders must not suddenly increase the intensity to 100 % of their force potential. The levered person needs to be given enough time to evaluate their pain and initiate a tapping signal. For better

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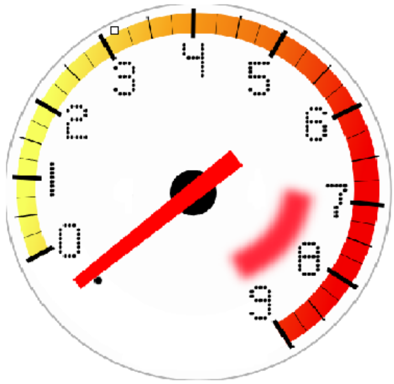


Figure 55. Tachometer

instruction of pairs, it is helpful to imagine a tachometer in a car which gradually accelerates from a low speed to a higher value.

## 2.6 First Aid in Teaching Professional Self-Defence

Training in martial systems, specifically martial sports, martial arts, and self-defence systems, poses certain risks of injury, where injury or sudden deterioration in health may occur. Injuries are part of the most serious events that can permanently change the health status of a large part of the population. Injury means damage to health which usually occurs suddenly, by the action of an external force that exceeds the intensity of the adaptive capacity of the human body (54). It could be expected that injuries cannot be prevented because they occur in sudden, unexpected situations. However, this is not the case. Tošovský (115) states that most injuries repeat in the same way on a regular basis. The first step that a teacher can take is making students assess their own health status and possible health restrictions before starting a professional self-defence course. As soon as injuries or sudden changes in health condition occur in their surrounding, teachers and instructors should be able to take basic steps and measures to save lives or improve injured persons' health.

A gym is a space adapted for safe training of physical actions. Nevertheless, injuries do occur in the teaching of self-defence. However, the occurrence

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of injuries is typical of any physical activity. The closest comparison with the teaching of self-defence systems is provided by physical education, which is taught at primary and secondary schools. Similar methodological principles, composition and content of lessons and complex demands on the musculoskeletal system apply at schools. Risks of sports injuries in pupils significantly depend not only on the type of sporting activity and the physical condition of pupils, but also on their age (96). Taking a closer look at the results of the reported school accident rate, since the school year 2006/2007, the most common place of injury has been during physical education lessons. Breaks only come second, together with other subjects. This is also confirmed by Tošovský et al. (115), who state that physical education, together with practical internships, are courses/subjects in which, according to statistics, the highest number of school injuries occur, regardless of whether teachers made a mistake or not. Reported school injuries in the Czech Republic have an increasing tendency. Over the last ten years, there has been an increase by more than 10,000 reported injuries. This increase may be conditioned by a more responsible approach of schools to reporting all, even minor injuries. On the other hand, it may also point out that the current generation has increasing problems with motor skills and habits.

Table 8. Reported school injury rates 2006/2019

| School year | Injuries total | Increase compared to previous year | Kindergartens | Elementary schools | Secondary schools | Higher vocational schoos | Other | Place of injury | Type of injury |
|---|---|---|---|---|---|---|---|---|---|
| 2006/2007 | 31,149 | | | | | | | | |
| 2007/2008 | 33,488 | 2,339 (7.5 %) | 679 | 22,759 | 9,771 | 279 | | Physical education 49.65 % Break 22.5 % | Limbs 80 % (upper limb 50.51 %) |
| 2008/2009 | 31,456 | | 698 | 20,530 | 9,288 | 198 | | Physical education 50.8 % Break 22.1 % | Limbs (upper limb 49.6 %) |
| 2009/2010 | 31,983 | | 793 | 20,852 | 10,338 | | | | |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2010/2011 | 31,890 | 1,220 | 17,831 | 12,839 | | | | |
| 2011/2012 | 36,626 | 1,036 | 24,648 | 10,228 | 714 | | | |
| 2012/2013 | 29,191 | 901 | 21,315 | 8,047 | 495 | | | Limbs (upper limb 48.5 %) |
| 2013/2014 | 31,441 | | 21,315 | | | | | Limbs (upper limb 48.2 %) |
| 2014/2015 | 38,710 | | | | | | Physical education Break | Limbs upper limb |
| 2015/2016 | 41,648 | 1,421 | 26,145 | 10,612 | 38 | 3,432 | Physical education Break | Limbs upper limb |
| 2016/2017 | 43,177 | 1,635 | 26,832 | 11,048 | 38 | 3,624 | Physical education Break | Limbs upper limb |
| 2017/2018 | 44,572 | 1,657 | 27,994 | 11,083 | 49 | 3,789 | Physical education Break | Limbs upper limb |
| 2018/2019 | 45,726 | 1,697 | 28,945 | 11,245 | 47 | 3,792 | Physical education Break | |

Annual reports of the Czech School Inspectorate. 2007–2019 [online]. 1 December 2007-1 December [8 January 2018]. http://www.csicr.cz/cz/dokumenty/Vyrocni-zpravy/.)

A closer look at the reported school injury rates shows that most accidents are registered in primary schools (up to 70 %), followed by secondary schools (28 %). The riskiest age is 13–16 years. Up to 50 % of injuries occur during physical education. More injuries are recorded in boys than in girls. The most commonly injured part of the body is the upper limb, followed by the lower limb and the head. The most commonly reported cause is an unfortunate accident.

Information on reported injuries in the teaching of professional self-defence, which forms a specific group within study subjects, is difficult to obtain. Teaching takes place in private courses, where the registration of injuries is not guaranteed. In the case of teaching within sports clubs

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and associations, the situation is similar, as sports organizations are not obliged to report the accident rate of their members. The reported injury rate could be registered by insurance companies, but only for specific insurance events of their clients. However, professional self-defence is also taught at selected secondary schools with a focus on the military and police sectors, such as the Security Law Academy with a network of five secondary schools in the Czech Republic. Here, it is possible to provide valid information on the basis of mandatory registration of injuries in teaching. Students of these study programmes complete an average of four hours of the course Professional Self-Defense (Special Physical Training) per week over a period of ten months within a four-year study. In general, students complete 640 lessons of teaching. In addition, throughout their study, students participate in a number of exhibition events and other trainings that are indirectly related to the teaching of professional self-defence (for example, survival courses, shooting courses or tactical courses).

Reported injury rate data come from five school years, from September 2015 to July 2020 (Table 9).

Table 9. Reported injury rates in the teaching of special physical education

| **School year** | **2015/2016** | **2016/2017** | **2017/2018** | **2018/2019** | **2019/2020** | **Total** |
|---|---|---|---|---|---|---|
| **Total number of students** | **130** | **120** | **122** | **154** | **142** | |
| **Injured part of the body** | | | | | | |
| Little finger | 2 | 3 | 4 | 3 | 3 | **15** |
| Wrist | 1 | 1 | 3 | 4 | 3 | **12** |
| Thumb | 1 | 1 | 4 | 2 | 3 | **11** |
| Bumped forearm | | 3 | 2 | 3 | 3 | **11** |
| Upper limb fracture – hand | 3 | 3 | 2 | 1 | 1 | **10** |
| Forearm fracture | 1 | 3 | 2 | 2 | 1 | **9** |
| Elbow contusion | 2 | 1 | | 3 | 2 | **8** |
| Palm | 1 | 2 | 1 | 1 | 2 | **7** |
| Shoulder dislocation | 1 | | 1 | 2 | 1 | **5** |
| Little toe | 2 | 2 | | 2 | 3 | **9** |
| Knee | | | 1 | 2 | 1 | **4** |


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| | | | | | | |
|---|---|---|---|---|---|---|
| Ankle | | 1 | | | 2 | **3** |
| Head | 1 | | 1 | | 1 | **3** |
| Cervical spine | | 1 | 1 | | 1 | **3** |
| Phalanx of finger of upper limb | | | 1 | | 1 | **2** |
| Back (not specified) | | | | | 2 | **2** |
| **Type of movement action** | | | | | | |
| Strike | 4 | 9 | 6 | 7 | 5 | **30** |
| Elbow strike | 2 | 2 | 2 | 6 | 3 | **15** |
| Leverage | 2 | 2 | 2 | 2 | 2 | **10** |
| Throw | 2 | 1 | 2 | 2 | 2 | **9** |
| Wrist leverage | 2 | 2 | 1 | 1 | 2 | **8** |
| Falls | 1 | 1 | 2 | 2 | 1 | **7** |
| Face hit by explosive | 1 | | | | | **1** |
| Push up | | | 1 | | | **1** |
| **Type of movement action: not specified** | | | | | | |
| Collision with a classmate | | 2 | 3 | 1 | 4 | **10** |
| Demonstration of a grip | | | 1 | 3 | 3 | **7** |
| Demonstration of self-defence | | | 1 | | 3 | **4** |
| Training | | 1 | | | 2 | **3** |
| When lifting off the ground | | | 2 | | 1 | **3** |
| Moving backwards | 1 | | | 1 | 1 | **3** |
| Falling for no reason | | 1 | | | 1 | **2** |
| **Other records** | | | | | | |
| EMS call | 2 | 3 | 2 | 1 | 1 | **9** |
| **Gender** | | | | | | |
| men | 7 | 6 | 10 | 7 | 10 | **40** |
| women | 8 | 15 | 13 | 18 | 20 | **74** |
| **Total** | **15** | **21** | **23** | **25** | **30** | **114** |

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These data show that over the past five years, upper limb injuries have significantly predominated. These are reported with the highest specification, in contrast to the lower limb, the head area and other areas, and also show the highest differentiation. The lower limb comes second, followed by the head and the back areas. The causes of reported injuries are most often strikes with no further specification. The second most common cause of reported injuries is leverage and, especially, wrist leverage, followed by strikes with specifications for the elbow, as well as throws and fall techniques.

It is not possible to determine exact values for individual groups because a certain part of the reports does not specify the exact cause of injuries, for example "collision with a classmate". Nevertheless, it is clear that injuries mainly affect the upper limb, especially parts of the hand, and that the most common mechanism of injury is striking movement action.

### 2.6.1 Informed Students

Students should be encouraged to report a change in their health to their teachers. Teachers should ask students about health restrictions at the beginning and end of each training session. When the health restrictions are compatible with the completion of the training, teachers agree with their student on possible relief from specific exercises. When teachers do not know about students' health restrictions, they can reprimand them for not fulfilling specific movement tasks, select them for technique demonstrations and the like. If an injury occurs or a medical restriction develops during a lesson, teachers should record this in relevant documentation at the end of the lesson. When teaching self-defence is divided into thematic courses, this gives teachers an opportunity to explain prevention and focus on specific risks before starting the training. Also, Grivna et al. (54) states that, in connection with the prevention of injuries, it is important to implement a systematic education of pupils and provide appropriate information regarding possibilities and mechanisms of injury occurrence.

### 2.6.2 First Aid

The following recommendations focus only on the most likely risks of injury, based on practical experience. These may include loss of consciousness,

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inhalation of a foreign body (being out of breath), bleeding (nosebleeds, skin ruptures, most often on the face), foreign bodies in wounds (eye injury), shock, most often associated with injuries to the abdomen and the head, joint injuries like distortion and dislocation, muscle injuries and epileptic seizure[8].

When an injury occurs during the training in professional self-defence, first aid usually means preventing deterioration of victims' state of health and ensuring conditions for their treatment, calming down, recovery or transport. Sudden situations often result in stress. Injured persons often moan, cry and have cramps. In some cases, they vomit or bleed. In this case, it is important to control emotions and prevent panic. It is always advantageous to immediately arrange for other cooperating rescuers and helpers from among the students (calling a rescue team by mobile phone, informing another teacher or the school management).

In the worst cases, teachers may face loss of consciousness: then, it is vital to immediately end all exercises and check whether the injured student responds to stimuli. If he/she does not react to shaking his/her shoulders or loud address, teachers must always call emergency services. If the student does not respond and does not breathe, it is necessary to follow the latest guidelines for cardiopulmonary resuscitation procedures.

Teachers may also encounter suffocation, most often caused by airway obstruction by a foreign body. During the training, the tongue may become stuck or a foreign body (chewing gum) may be inhaled. It is important to encourage the victim to cough. If the cough is not effective, five strikes are applied between the shoulder blades. If even these are not effective, up to five abdominal epigastric compressions are performed [19,25].

Teachers may often encounter situations in which bleeding occurs, most often bleeding from the nose, torn skin on the face, etc. Especially the head area is very well perfused, so wounds in this area often bleed profusely. It may be external venous bleeding in the form of surface cuts, lacerations, or abrasions. Sharp objects are not included in standard self-defence training. However, there are training aids that may create lacerations or cuts (for example, the sharp edges of a training pistol, the striking surface of a telescopic baton, a training knife made of metal or hard plastic, etc.).

[8] Czech resuscitation council. (online). 2020. (Access st: https://www.resuscitace.cz/)


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In cases that are probably not directly related to self-defence training, external arterial bleeding may occur, especially in connection with a fall on the gym equipment and the like. In the case of external venous bleeding, a pressure bandage is applied, and the injured part of the body is raised above the level of the heart. In the case of major bleeding from lacerations or cuts, it is necessary to seek medical treatment. Bleeding from the nose is a disruption of small blood vessels inside the nostrils. The victim must sit down, lean forward and allow the blood to flow freely. A cold compress is applied to the nape of the neck or to the forehead of the victim. If the bleeding does not stop within 30 minutes, teachers must seek professional help [19, 25]. Teachers must make sure that students comply with the ban on wearing rings, chains or earrings. All these items increase the risk of injury to all participants. A foreign body in a wound most often occurs in the case of an eye injury caused by a tiny object (insect, dust); the eye must be rinsed with a special solution or water. Larger and sharp objects must not be pulled out; the eye must be covered with a sterile cover and professional treatment is to be sought.

Shock is an acute condition in which circulatory collapse occurs, resulting in reduced blood flow and oxygenation of the tissues. The affected person stops communicating, looks sleepy and their skin is cold, moist and pale. Their pulse is not palpable. Reasons include, for example, concussion as a result of the head having been hit, an injury to the abdomen as a result of a kick to the lower impact area, or an injury to the spine as a result of a failed throw. Shock treatment procedure includes an anti-shock position aimed at increasing the return of blood to the heart and vital organs. The affected person lies on their back, the upper half of their body is lowered, the lower limbs are supported so they are at least 30 degrees higher than the body. In the supine position, the lower limbs can also be lifted upwards perpendicular to the body, which is called the auto-transfusion position. It is necessary to call the Emergency Medical Service, pay attention to thermal comfort and not give fluids to the affected student. If a spinal cord injury is suspected, the victim must not move.

Sprains are the most common ankle joint injuries. It is advisable to apply a compress, immobilize the joint and place the injured limb in a raised position. Dislocations most often affect shoulders, fingers and jaws. Causes of muscle injuries may include sudden movements, lifting objects or poor landing. The muscle is usually stiff or may be cramped. During muscle

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cramps, straining the affected limb and slowly stretching the muscle group is helpful. One possible health complication in training is an epileptic seizure. Epilepsy is a disease of the brain in which neurons send bad signals to the body, which responds in different ways. Not every epileptic seizure looks the same. When should teachers call the Emergency Medical Service? If it is a major seizure lasting more than five minutes, if a disturbance of consciousness occurs, or if the victim is injured or does not feel well during the seizure [(80)].

Teachers cannot prevent uncontrollable factors that threaten students' safety. However, they can develop their skills and study on their own so as to improve their capacity to detect controllable factors, such as technical equipment or training aids in the training space, their status and condition. Teachers must also have excellent knowledge of methodological procedures and legislative regulations and must follow them. Knowledge of first aid, willingness and capacity to help are a priority and are necessary for the profession of self-defence teacher.


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# 3. chapter
# **Tactical Contexts in Model Situations**

The main goal in teaching professional self-defence for specialized IRS (Integrated Rescue System) professions is to prepare students for real conflicts that they may encounter in the performance of their work. One of the tools used is model situations simulating the most common forms of attacks. Model situations cover all phases of conflicts and their development, especially the pre-conflict phase. The aim is to teach students how to avoid direct aggression and adapt to changing situations, combine verbal defence with preventive movement actions, respond to unexpected situations and recognize danger well in time. Quite an opposite situation reigns in martial sports training, and therefore it is not right to confuse training concepts. The goal of training martial athletes is to prepare them for competitions and defeating their opponents. The training focuses only on the conflict phase and drilling isolated movement actions. Martial athletes know what they are preparing for and under what conditions conflicts take place. Quite opposite conditions apply to self-defence systems, which primarily teach students how to avoid conflicts.

Professional self-defence teachers must put every physical action in a broader context, make it into a story. In order to do this, teachers use knowledge regarding conflict cycles, the Cooper scale of preparedness, the pyramid of values and, above, negotiation strategies. A correct understanding of the philosophy of the training of students, non-athletes, in professional self-defence minimizes risks of injury because its curriculum prioritizes practicing soft solutions over aggressive fighting technique drills. Such techniques are also included in training, but always in combination with relevant protective procedures and always with respect to initial potentials of students.


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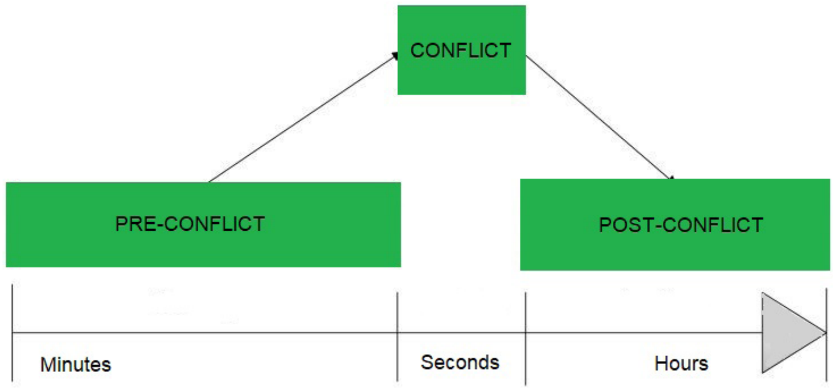


Figure 56. Conflict diagram

## 3.1 Conflict Cycle

Conflict situations can be described in three phases:

- pre-conflict
- actual conflict
- post-conflict

### 3.1.1 Pre-conflict

The pre-conflict phase focuses on the pre-conflict period (120). Attackers assess their victims and address them. In the case of unexpected spontaneous attacks, the pre-conflict phase can be very short and insignificant. An important role is played by defenders' experience, their observational talent, their sense of "assessing" attackers. It is important for defenders to perceive signals sent by a potential attacker. Such signals may include a sudden change in behaviour.

The potentional attacker:

- suddenly stopped talking
- noticeably changed their facial expression or posture
- changed their respiratory rate

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- strengthened visible parts of their body, such as fists or teeth
- began to use an informal way of address and vulgarisms in communication
- began to touch their pockets

Appropriate communication strategies are key verbal self-defence tools in a pre-conflict situation. These may include, for example, a “broken gramophone record” (repeating a simple request over and over again), for example:

**“Do not approach me, sir!”**
**“Stay where you are!“**

or the “open door” strategy (non-conflict action expressing understanding of the aggressor’s position and showing goodwill), for example:

**“...but I can see your point there.”**
**“I see why you are worried about your relative.”**

It is important for teachers to require students to apply verbal tools before actual physical actions. In the pre-conflict phase, it is also important to master efficient techniques for setting and maintaining the communication distance, establishing communication attitudes and possibly preparing self-defence means in one‘s hand.

With regard to tactical contexts of communication approaches (for example, techniques of giving up by putting the hands up), important testimonies for possible judicial implications may arise in the pre-conflict stage. Evidence such as statements, video recordings of witnesses, etc. can indicate who was the originator of the conflict, who, on the other hand, tried to withdraw from the conflict, and who made an effort to negotiate.

### 3.1.2 Conflict

In the conflict phase, a defender and an attacker clash (120). Situations in which it is clear who the attacker and the defender are are more favourable. Attackers are known in advance, their attack is visible and defenders have a few priceless seconds to get ready for defence. Forms of attack

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with gradual conflict escalation, aggressor's provocation and shortened distance up to personal space disruption are less favourable. There is no clear solution to them. Defenders have the right to defend their safe space around them. However, from the legal point of view, they must not become attackers.

The conflict phase contains what is most often seen in the media. A defender and an attacker enter into a conflict and fight. This is the part of the conflict that, for example, random witnesses record on their mobile phones. Usually, nobody notices pre-conflict phases and if somebody does, they do not record it. Conflicts are not always preceded by loud verbal communication, striking non-verbal communication or other manifestations. Recordings usually contain only specific physical violence, which is attractive to viewers of evening TV news.

### 3.1.3 Post-conflict

The post-conflict phase is characterized by events following the actual conflict (120). In this phase, however, it is no longer possible to take anything back. What happened, happened. On the other hand, the post-conflict phase is very easy to record compared to the previous phases. These include, for example, arrival of an ambulance and medical care provided to defenders and attackers, arrival of police officers, identification of witnesses and securing evidence for later investigation, gathering samples, possible other media reports regarding implications in the form of psychologists' involvement, litigations, court trials and the like.

From the above conflict pattern, it is clear that individual phases differ in their duration. The actual conflict itself is the least interesting, the shortest and, in a way, the simplest. It can last just one second. The phase that precedes it is a bit longer and lasts minutes. The post-conflict phase is the longest. This includes not only medical but also psychological consequences dealt with in court, appeals to other judicial institutions and the like. In real time, such circumstances can represent a period of several months.

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## 3.2 Cooper Scale of Readiness

Mental condition affects how one reacts to a threat. The key concept is defenders' degree of vigilance, which determines the speed of response to a threat. Jeff Cooper (2006) created a vigilance scale that immediately spread in the self-defence sphere worldwide. The scale consists of four colour-coded vigilance modes (the "semaphore") determining readiness for attack. Cooper's vigilance scale is related to decision-making processes and reaction times in conflict situations. Teachers should interpret individual modes of vigilance and attention and translate them into specific model situations.

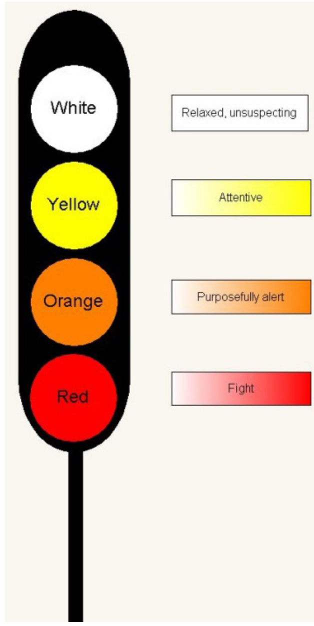


Figure 57. Semaphore of Vigilance Modes

### White

Attacks to healthcare professionals whose vigilance level corresponds to the white colour can have the worst consequences. Reactions of such healthcare professionals are slow and "frozen", as these persons are frightened. For example, they are not able to quickly react to attack weapons. Only what an attacker does wrong increases their chances for survival. Paramedics having the white level of vigilance should only work in places and situations that are totally safe.

### Yellow

Healthcare professionals should be set in this mode when entering an unknown environment. There is no particular danger present, but their state of mind is set for potential attacks, so far without specifying their time and place. It is possible to be in this mental state for a very long time. In the yellow state, healthcare professionals are able to process information from their surroundings and look for potential threats. Paramedics should set this mode each time they get out of the ambulance and are about to perform professional procedures, even if the current situation appears to be risk-free.

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**Orange**

Healthcare professionals should be set in this mode when something is wrong and has caught their attention. They have become alerted to a specific danger and are turning their attention to it in order to confirm or reject it. In this state, healthcare professionals consider and prepare a potential self-defence, deciding: “When the attacker does this, I will do this”. Remaining in the orange state of mind is stressful, but it is possible to remain in it for as long as it is absolutely necessary. If a danger proves not to be real, healthcare professionals move their vigilance degree back to the yellow state. This can include, for example, establishing visual contact with a suspect person, such as a dominantly gesturing family member or an aggressive homeless person. Healthcare professionals must, in this case, divide their attention and keep a significant part of it focusing on a potential threat in order to keep a potential aggressor in their field of view at all costs. This is the moment to start cooperation of two or more defenders where one shifts full attention to the potential aggressor in order to keep him/her busy, and the rest of the team secure an advantageous position outside the potential aggressor’s field of view. In this phase, it is also advisable to get possible technical self-defence means ready in the hand, such as tear spray.

**Red**

Setting a medical professional in this mental state means fighting. A number of interrelated physiological reactions occur. Blood moves to large muscle groups. Memory is diverted from cognitive processes. Self-defence reactions that are not based on natural instinctive reactions or reflexes become difficult to activate (30). What paramedics have learned in self-defence courses becomes decisive at this moment. What also matters is their resistance to pain, speed of reactions, muscular condition and fitness, experience from other sports and many other individual characteristics. Within theoretical tactical training, it is appropriate to discuss with students whether they have ever thought about their own behaviour and whether they are set to the above levels of vigilance in everyday life. In general, people make a number of tactical mistakes when traveling on public transport or walking about the city. This includes, for example, using headphones listening to music. These block the second most important sense that the human brain has. People lose vigilance even when walking in pairs. They focus on the communication with their partner and lose track of the environment. A specific category of distraction factors are mobile

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phones, on which part of the population today is literally dependent. These are just some examples of mistakes that are often seen and can result in a defender's zero chances at the moment of attack.

**The cornerstone of success is to start thinking about the environment in which I am moving around, focus on what I can expect and determine whether the setting of my attention corresponds to the above.**

A few words about the author of Cooper's readiness scale:

> *John Dean "Jeff" Cooper (10 May 1920-25 May 2012) served in the Marines and fought in two wars. These were World War II and the Korean War. In his professional life, he also specialized in teaching practical shooting. In addition, he focused on the hitherto underestimated area of psychological training. His lifelong experience showed that the most important thing for survival is not the weapon, but the setting of the mind. The established system of mental attention has become an essential part of the training of most security forces around the world. However, different variants of the basic four-degree scale can be encountered. US Marine Corps instructors added one more colour – black. It complements the red colour and characterizes the inability to respond adequately due to being totally overcome and exhausted. Other self-defence schools consider red as a mode of verbal self-defence and black as a mode of physical self-defence* (30)*.*

## 3.3 Negotiation Strategies

Recognizing when it is possible to solve a conflict situation by agreement (verbally in an assertive way) and when not is probably the most difficult task for defenders. These, in addition, tend to hope until the last minute that the conflict will be solved "in a good way" (without escalation). No one wants to risk a fight and a risk of injury. Evaluation and decision must come as quickly as the attacker's behaviour changes.

**This raises a fundamental question: According to what should we decide?**

For simplicity, which is a basic prerequisite for success in decision-making processes, it is possible to distinguish only two possible variants of


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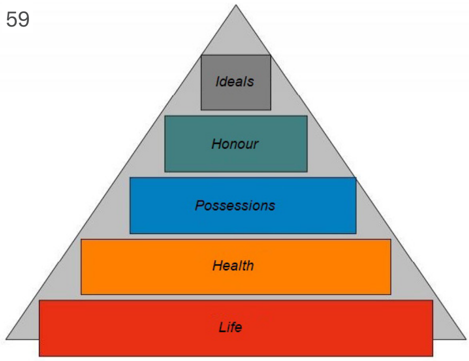


Figure 58. Diagram of the decision-making process
Figure 59. Pyramid of defender priorities

solution that defenders have. A variant in which it is possible to negotiate and calm down the attacker with appropriate communication or retreat, and a variant in which this is not possible. At the same time, such a decision-making process should respect the legal status of necessary defence.

The right decision should be based on a system of values. Sorting them in order of importance can generate a key. The value system is displayed in the defender's pyramid of priorities.

The base of the pyramid marked in red represents life as the highest value. Defenders should not enter into situations where they are in danger of losing life immediately. For example, there is:

- a firearm
- a cold weapon
- another weapon in the attacker's hand or within close reach of the attacker
- a psychiatric patient in the attack
- a group of armed attackers

These examples are only given for illustrative purposes and do not guarantee a clear guide to an error-free assessment of a situation. Therefore, these recommendations should be interpreted as something that can help increase a defender's chances of survival.

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The second level of the pyramid marked in orange is closely related to the base of the pyramid. The difference between an immediate threat to life and a threat to health is very narrow.

**Posessions**

The middle level of the pyramid is something that defenders most often mistake over the values of life and health. There were cases in which the owner of a shop engaged in a fight with an armed robber, even though they did not primarily endanger the owner's life, but demanded "only" the goods. The cases ended differently. In some cases, the owner managed to defend their goods and the robber fled. In other cases, owners paid with their life for such conduct. However, cases where a shop owner did not defend themselves but was still killed by a robber in order to eliminate possible witnesses of the theft are also recorded. In one case, a shop owner fired at a robber who was already leaving the shop with stolen goods and killed the robber. The owner saved their possessions, but their act could no longer be considered a necessary defence. So, prioritizing one's own life over protecting possessions is not a 100 % recipe for survival. However, this mental procedure (i.e. assessing values) certainly increases the probability of a defender's survival.

**Honour and Ideals**

The last two levels of the pyramid, labelled "Honour" and "Ideals," are other areas where defenders often make mistakes. In each situation, it is necessary to consider risks of possible escalation of a conflict. History is not infallible, but as far as it is known, not a single case has been reported in which defenders lost their life or were injured as a result of a verbal attack. On the other hand, there are a large number of cases where attacked people died in a fight initiated by themselves on the basis of a previous verbal incident. Relations of individuals to their personal honour is, of course, conditioned primarily by the historical period and education, which determine the value system of human beings.

**Conflict**

The diagram of procedures chart in conflict situations must be interpreted correctly. For ordinary citizens, retreat is the ideal solution at the time of negotiation failure. It is true that, in terms of legislation, paramedics do not, with minor legislative exceptions, differ from ordinary citizens. However, paramedics must complete a task on the scene, namely some medical procedure provided to a patient who needs it.

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Figure 60. Diagram of procedure in conflict situations


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**Attempt to Negotiate**
Attempting to negotiate offers many possibilities, such as settling the dispute amicably or, for example, obtaining additional information and time.

**Negotiation Possible (blue column)**
The left part shows the course of conflicts in which it is possible to negotiate. Most likely these have the form of verbal aggression. The moment the negotiations bring results and the attacker can be calmed down, made busy, driven away, persuaded, "gained", discouraged or demotivated in their intended attack, it is possible to continue medical work. During the negotiations, defenders improve their position with the help of tactical rules: communication distance and communication approach.

**Aggression lasts**
When a verbal attack lasts and the verbal self-defence of medical staff, including tactical measures, has not deterred the attacker from behaving aggressively, a problem of potential threat arises. A potential threat is dangerous due to unpredictable risks of sudden changes. These are situations in which the attacker threatens the staff with particular appeals, berates them, is rude, nervously walks around, disrupts communication between rescuers, shouts over them and the like. In civil self-defence, the recommended approach is retreating, so as to make it clear whether or not the attacker is willing to pursue the defender. However, paramedics choose to leave their patient only in the greatest emergency because the patient needs them. At the same time, however, paramedics should not endanger their own life. It is not always possible to transport patients to the ambulance, which provides an ideal solution for medical staff to retreat to relative safety. Paramedics are in a difficult situation at such a moment because the evaluation of the situation here and now is purely subjective and involves a number of factors.

**Calling the Czech police**
In any case, paramedics, at an appropriate time, should request assistance by the Czech police, ideally well in advance of the escalation of a conflict.

**Negotiating not possible (red column)**
The right part of the diagram shows the procedures designed for an unfavourable course of conflicts. Defenders have no problem recognizing the threat because it is clear and unambiguous. In such situations, attackers

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reach for a visible weapon, realistically threaten through their movements (for example, intimidation in the form of jerking or twitching), reach out, announce that they are going to attack, and so on. From a certain but somewhat borderline perspective, as already mentioned, these situations are better than those that are calmer but unreadable.

**Retreat possible – Whoever runs away wins! – Retreat not possible**
A practical selection of specific self-defence techniques is offered in the column which is located on the far right. Retreat is impossible. The reason may be the attacker holding or strangulating the defender, and the like. The attacker can also block the defender's exit from a narrow space. The list offers technical possibilities of self-defence in both long-distance and short-distance combats.

**I have space**
If defenders are not held by attackers at a short distance and can reach out, effective attacks on the face with extended upper limbs and kicks to the genital area with lower limbs are recommended.

**I have no space**
When attackers "stick" to defenders and thus prevent them from stretching out to attack, strike or kick, it is possible to use technical elements for shorter distances. Upper limbs allow for very effective elbow punches, and lower limbs enable knee kicks. At the same time, it is true for all conflict combat situations at the moment of repelling the initial attack that defenders should not continue the fight but should retreat to a communication distance in a tactical communication stance and to a sufficient safe distance from attackers.

### 3.3.1 Implementation of Model Situations in Teaching

After students get acquainted with the basic composition of physical actions in introductory courses, teachers should manage the teaching as model situations. Students do not train isolated movement elements, but immediately apply them in a broader context and learn to adapt to changing situations.

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Figure 61. Elbow and shoulder leverage (Gjaku ude garami) in one-to-one mode
Figure 62. Elbow and shoulder leverage (Gjaku ude garami) in two-defender mode

1. **One defender versus one attacker**: In practical exercises in pairs, students learn to perform a "one-to-one" technique. They have enough time for safe acquisition of this technique.
2. **Two defenders versus one attacker**: In groups of three, students learn the same technique in which a second defender participates.
3. **One defender versus a group**: In group training (four or more students), a defender learns tactical contexts that arise with a group of attackers. These attackers exert psychological pressure on the defender, shorten the distance and prepare to attack. Defenders are forced to implement a technique in a shorter time and with greater accuracy. They may also use a pacified attacker as a living shield in some situations.

**Principle of three models**

If instructors manage the practice of self-defense techniques in the three models, they should follow their order. This guarantees control of the difficulty demands on students and thus control of possible injuries. The simplest scheme is one defender versus one attacker. In this model, both students have enough time to get acquainted with the application of the technique. The level of difficulty increases when two defenders have to cooperate on applying the same technique to an attacker together. At this stage, they should already have mastered the technique and be one level up. The most difficult form of model situation comes at the very end, where a defender must resist a group of attackers.


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# 4. chapter
# Requirements for Training Programmes of Specialized Professions in Health Care

*In order to train a defender in self-defence, it is necessary to follow a comprehensive plan with defined goals and means leading to achieving these goals. It would be easiest to choose such plans from already existing and proven groups of martial arts, martial sports or real self-defence systems. But is it possible? Currently, there are dozens of different martial arts schools with different histories and philosophical backgrounds. However, educational contents in the form of specific movement actions do not essentially differ from one another thanks to the common foundations of the Japanese Budo concept. These are easily seen especially in complex self-defence programmes, which, despite all efforts to achieve commercial innovation, always represent an effective "mix" of karate, judo, aikido and wrestling. Educational contents of combat systems can be extensive, and the time required to master them may be long. A question arises as to whether it is appropriate for healthcare professionals' specific needs to conduct training according to the existing combat systems or whether this is not possible, and a completely new and specialized programme must be developed. From the point of view of minimizing injury risk in training, the answer is a definite yes. First, it is necessary to exclude from the educational contents such physical actions that require long-term training, are not based on natural reflexes and movements of the human body and are conditioned by a high level of experience.*


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## 4.1 Available Combat Systems

Each combat system consists of techniques. Techniques can be divided into three phases: the beginning (entry), the course (the technique itself) and the end (osae)[9]. From the defender's point of view, the beginning is carried out, for example, by a contact soft or hard covering, a block, or a contactless step aside. The technique itself is a contact movement action that is used to overcome an attack (for example, leverage on the elbow and shoulder). The end of a technique usually means controlling the attacker, for example, in the form of immobilization of the attacker on the ground (preparation for handcuffing. Individual techniques differ from each other in their preferences for strikes, kicks, shoulder-throws, knockdowns, leverages and the like. The number of techniques, including their possible combinations, can be calculated, and the scope of the entire system can be evaluated. Combat systems that use boxing gloves are the simplest. They are also referred to as corner combats and contain a very low number of movement actions. The time required to master such a system is far shorter than in other systems. For example, the boxing sport system consists of three techniques: a direct punch technique (the "direct") and two arc punch techniques (the "hook" and the "uppercut"). A punch with a clenched fist together with a change of stance form the key element and the basis of boxing [(20)]. Boxers improve and improvize punch combinations in cooperation with evasive manoeuvres. The opponent's attacks are strictly limited by the rules, and it is not possible to hit the opponent from behind, from above, to the lower zone below the level of the abdomen. For sports needs, this system can be quickly mastered and is also easily measurable in combat competitions. On the other hand, this system does not deal with a large number of real attacks (such as throttling, attacks to the groin, grasping the clothes, and, especially, attacks from behind or "dirty tricks"). Sports systems cannot be simply taken over for training real self-defence without necessary modifications. However, it is possible to find among them specific techniques which are very effective and testable.

More versatile combat systems, whether sport combat systems (such as karate), traditional systems (aikido) or modern "street" systems (musado, allkampf-jitsu, krav maga, etc.) contain far higher numbers of techniques to equip defenders with necessary movement tools for a whole range of conflict situations. Techniques can be roughly counted in examination

[9] The term osae refers to only one possible ending, but there are also other ends as throwing or choking.

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regulations for specific combat systems. These usually use several dozen forms of movement within pupil levels, which eventually methodically lead to the first dan (so-called black belt examinations). Such comprehensive education provides technique security against attacks by strike, kick, grip, holding, throttling and against so called cold weapons, improvised weapons or firearms. Directions of possible attacks bring other needs to get specialized in downward attacks, attacks from the front, the side and the back, including a whole range of possible attack zones (upper, middle or lower zones).

On the one hand, it is desirable for the training system to be comprehensive and to prepare defenders for everything that a real conflict can bring about. On the other hand, the question is whether it is possible to apply such a system to individuals with limited time possibilities and a minimum previous level of experience. The healthcare sector has another requirement: defensiveness of the system. This means that physical actions should, in principle, seek to pacify attacks in a non-destructive way. Paramedics primarily protect life, not the other way around. Moreover, patients are often attackers. From a methodological point of view, such a system should prefer soft covers, not hard blocks. Pressure techniques on sensitive nerve endings should be preferred to strikes. To a greater extent, also leverage techniques should be preferred as these do not usually injure opponents, but help to control and smoothly immobilize them step by step.

From this point of view, a suitable system could be the Japanese martial art aikido, which meets the requirement of defensiveness. From a purely sporting point of view, the aikido system can be integrated among combats that specialize in techniques of deflection, immobilization and leverage, especially of upper limbs, and throws and pull-downs. The aikido system is based on a group of several basic movements, which are further developed into technique systems and their specialized complex structures. Most techniques are applied in three modes of attackers' stance toward defenders: both the attacker and the defender are standing; the attacker is standing, and the defender is kneeling; both the attacker and the defender are kneeling. The techniques are strictly divided according to the initial stance and the final movement in the form of omote (forward) or ura (backward).

Other possible implementations of techniques according to their direction include two groups: the soto (the defender performs the technique in front

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of the attacker), and the uchi (the defender performs the technique behind the attacker). Grips are divided into groups of cross grips, one-sided grips, grips with both hands and other variants. The methodology of the aikido system does not cover all forms of combat, for example stanceless combat, which is combat on the ground. Instead, it specializes in attacks directed primarily at the defender's upper body. This specific feature is probably related to the historical background of the aikido system, which is inextricably linked to the samurai weapon: the katana. Attacks were based on stance combat, in which both fighters gripped the weapon and tried to hit mainly the vital zones of the opponent's upper torso. In professional self-defence, the absence of combat on the ground would be a serious shortcoming, especially in the medical environment, where paramedics may face various types of attacks while providing treatment in a kneeling position on the ground, or bending over an injured person, who may surprise medical professionals by unpredictable reactions.


Figure 63. Techniques and forms of movement in the aikido system

The aikido system contains approximately ten basic and ten specialized techniques that can be performed in two initial forms (soto and uchi) and in two final forms (omote and ura).

In a random selection of the sankyo technique, one resulting technique is created when the attack is performed from the front in the tachiwaza stance (the defender's stance on the feet), in an attempt to perform a grip, and in the case of the uchi initial phase (under the attacker‘s upper limb in rotation) in the form of omote (directing the defender's movement towards the front of the attacker's body).

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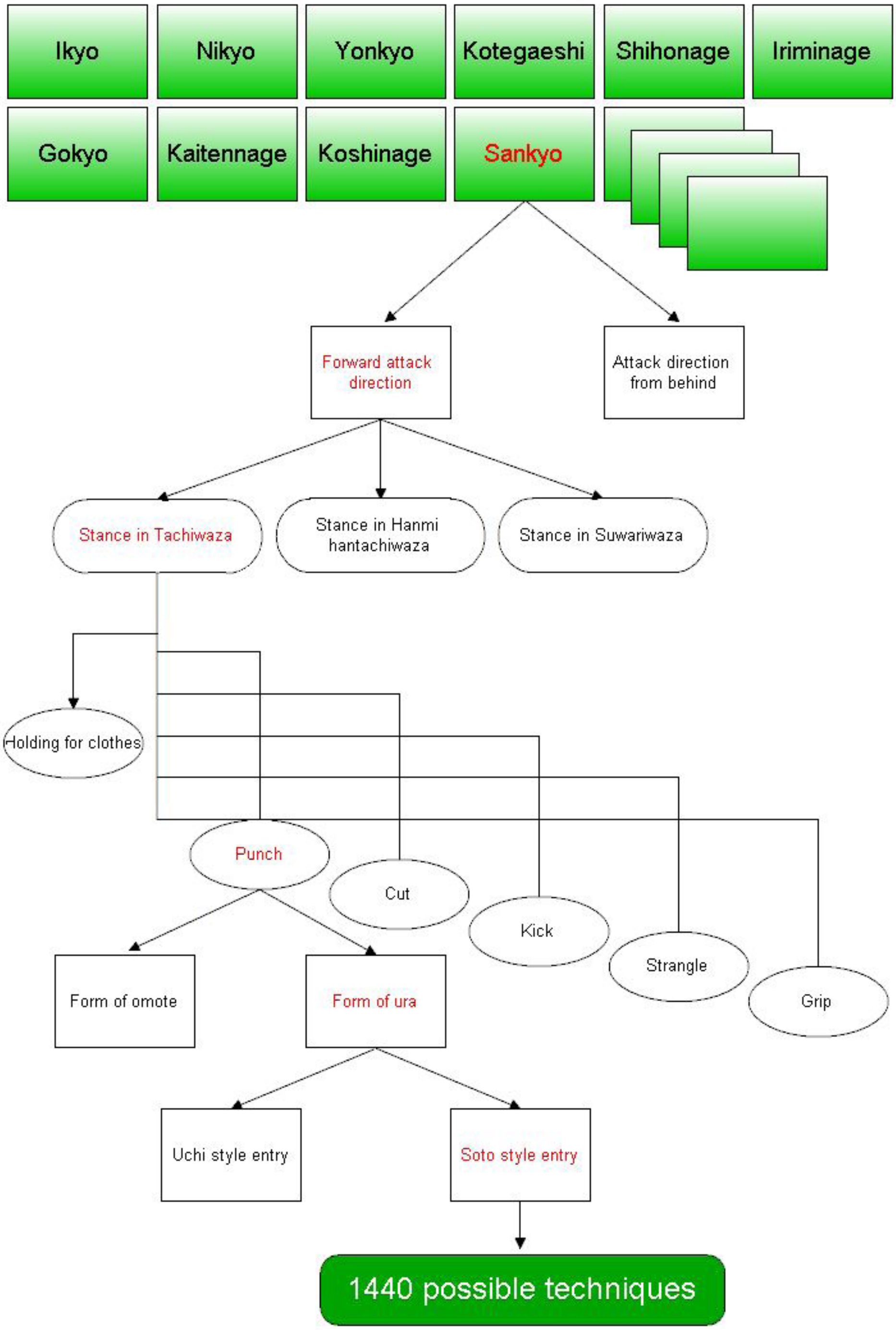


Figure 64. Selected aikido techniques in basic combinations

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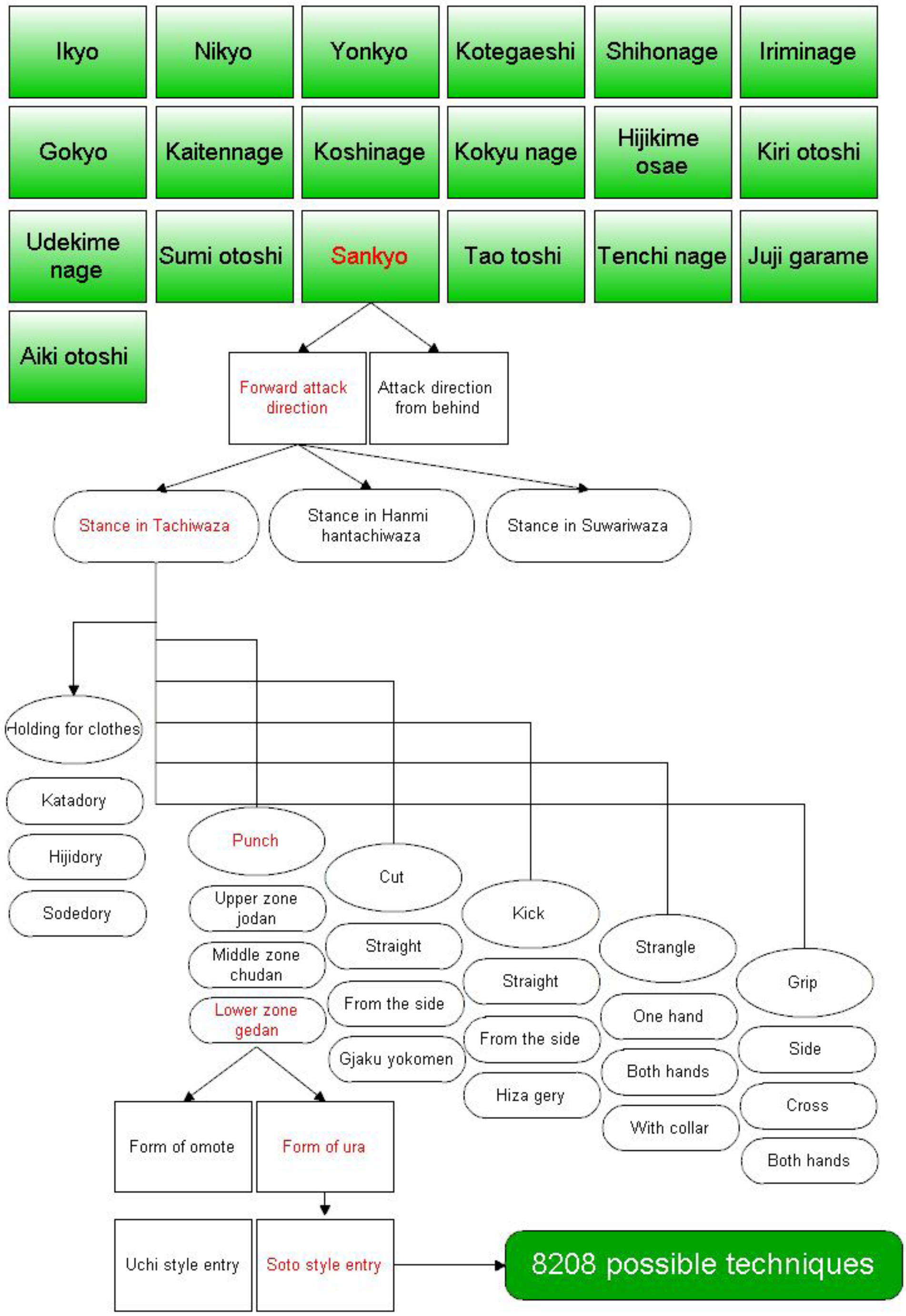


Figure 65. Aikido techniques in all combinations


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Starting with an attack by grip, it is possible to combine four techniques, which are different during their course and in their final ending (osai, holding the attacker, immobilization of the attacker on the ground). There are six basic forms of attack, which results in 24 combinations. Forms of attack can be started in three stances, resulting in 72 combinations. Multiplying by two, which is the number of possible directions of attack (from the front and from behind), gives the number 144. The final multiplication by 10, which is the number of basic creative techniques[10], can result in the final number 1,440.

If a defender could practice one technique in one minute, the entire programme demonstration would last 24 hours. However, the number 1,440 is not final, because the 4th level of "type of attack" does not include specific differentiations; for example, a grip attack can be divided into grip attacks with the same side limb, the cross limb or both hands. Strike attacks can be divided into three zones: upper, middle and lower. Attacks by holding a garment can be divided into three individual sectors (catadori – shoulder area, hijidori – elbow area, sodedori – wrist area). And cut attacks, which are made by the edge of the hand, can include shomen (straight cut), yokomen (slanted cut) or gyakuyokomen (cut by the hand with its back upwards). The final number could be even higher if the basic ten techniques included other techniques (koshinage, aikiotoshi, taotoshi, kiriotoshi, jujigarame, hijikimeosae, udekimenage, sumiotoshi, yonkyo). Thus, the whole calculation would be based on almost twice the number of techniques – 19 and not 10. This complete scheme, including all variants of officially classified techniques covering reactions to various forms of attacks, would reach the final number of 8,000.

Are there simpler systems? The karate system, which prefers strikes and kicks with limbs, is a kind of counterpart to the soft school of Aikido. Karate turned up 5,000 years ago and evolved from Chinese combat styles. It gradually spread to Japan. In the late 14th century and in the 15th century, it became a self-defence art of "bare hands", especially in connection with the ban on the use of weapons [(110)]. Today, different interpretations of this system may consider it art, sport or even self-defence. The three basic training means for defenders include kihon, kata and kumite. Kihon, or the "basic technique", includes techniques of stances, direct punches, swinging strikes, arching strikes, cuts, covers and foot techniques – kicks.

[10] Ikkyo, nikyo, sankyo, shihonage, iriminage, kotegaeshi, kaitennage, gokyo, yonkyo, koshinage, tenchinage.

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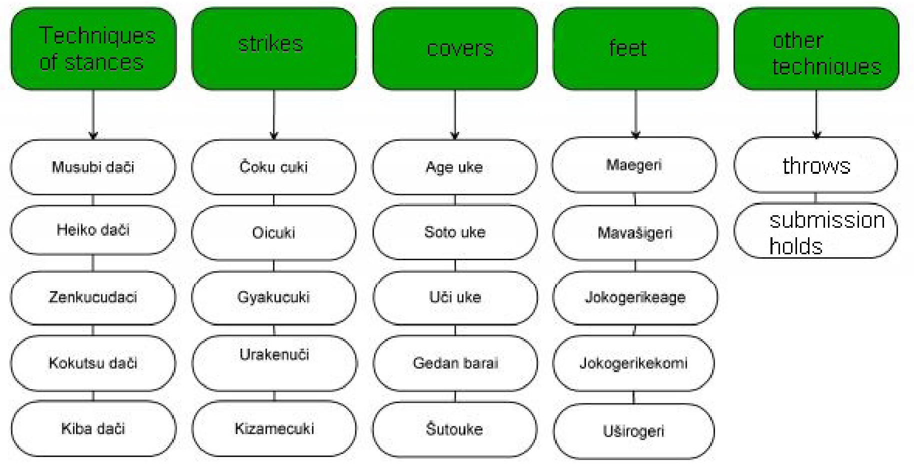


Figure 66. Karate techniques

Together with bends, throws, throw-downs and falls, these form the methodological basis of karate (62). From the overview of technique safety, however, it is clear that karate, in the sum of all physical actions, represents an extensive system, the mastering of which is not possible in a short time.

Another possibility is focusing on a system orientated towards soft techniques meeting the condition of defensiveness. Judo, unlike aikido, is not a purely martial art; it only has become part of the martial arts system due to its late development. Its methodological content can be expected to be less complicated, regarding its orientation towards the education sector and also with regard to the requirements of sports rules. In the judo system, two opponents compete trying to get the shoulders of the opponent on the ground using techniques of deviating the opponent from balance, and using throws and immobilization. The basic defender training means are: katamewaza and nagewaza. These are grips performed on the ground and grips performed in a standing stance. In a brief overview, these are holding, throttling and levering techniques, and techniques using the arms, hips and legs. However, a detailed look at the basic composition of the judo system shows that the content intensity is high.

In addition to martial sports and martial arts, we can draw special training elements from the last category available, which is the system of


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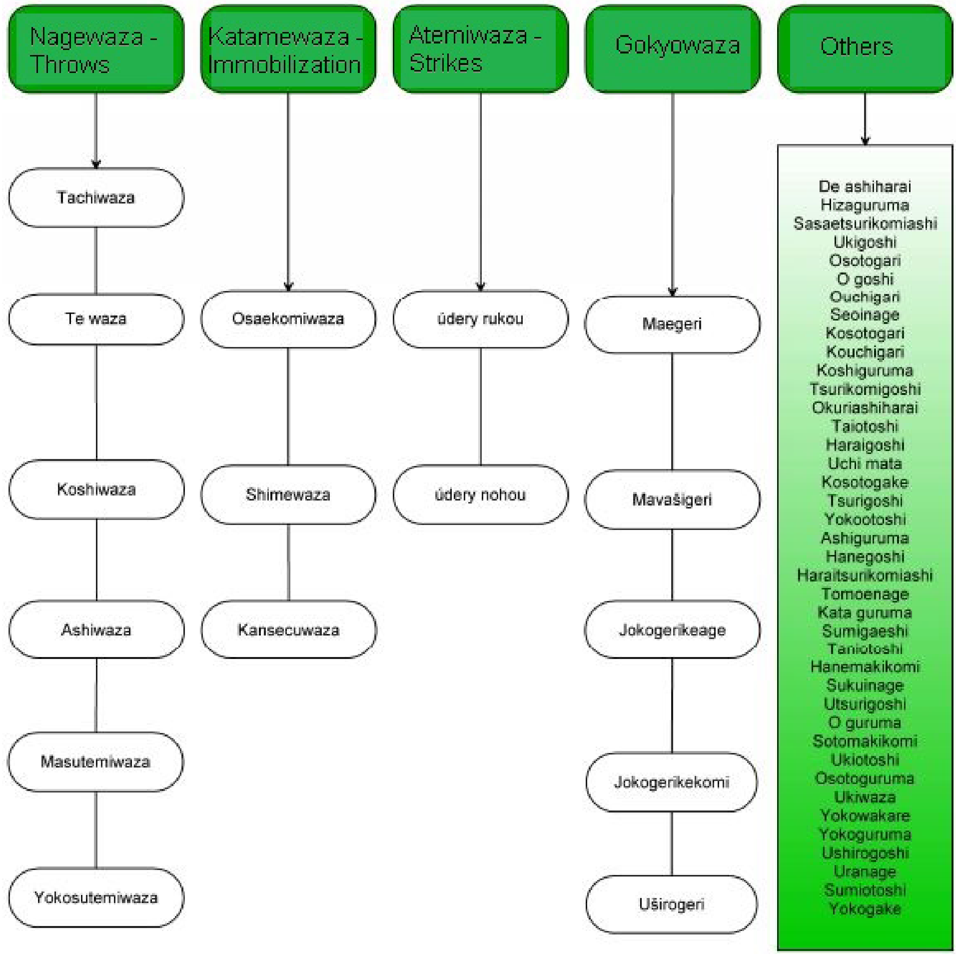


Figure 67. Judo techniques

self-defence. All current modern systems of real self-defence are based on traditional combat schools, which is why a large number of techniques can be found here as well. Another important issue is the functionality; it is not easy to determine which system is more usable in a real environment and which is less usable. Some self-defence systems also have their own sports applications, which brings additional marketing potential focusing, above all, on children and youth.


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“Western” combat or self-defence systems, completely or partially free from all Asian traditions, include the modern All Kampf-Jitsu (AKJ) combat system, which uses strikes, kicks, body bends, throwing and leverage, and standing and ground combat in order to stop any attack and thus protect the health or the property of a defender. AKJ can be included in the group of modern European schools of Ju Jitsu, which were established in the middle of the last century. This group currently contains over 330 basic defence techniques, three forms of combination (kihon) and ten forms of kata. Basic techniques include defence against strikes, kicks, throws, throttling and against weapons.

The Musado combat system is another of the modern, multifunctional self-defence systems, which is used by the Czech police sector and the Czech army. It is a quality system with a smaller membership base, which selects its candidates according to certain criteria. The system was introduced into the training of the Army of the Czech Republic in 1993 and has a significant place within the police of the Czech Republic in the form of sports clubs. Thanks to these strong partners, the Musado system does not need – and cannot – be promoted commercially, which is one of its strong advantages. The system methodology uses judo fall techniques: throw-overs, throw-downs and opponent blocking techniques. The aikido martial art provides leverage techniques, where police officers and soldiers learn to work with opponents’ energy. It includes combat elements in training for the needs of immobilizing opponents, for example, when handcuffing. Kicks and strike techniques are also important, because kicks and strikes are, in most cases, the decisive element that can completely reverse a situation in a short time. The Musado technique elements mostly tend to prefer the karate system and its sports subcategory Kick boxing, given the above reason of speed and efficiency. The relationship is also noticeable in the similarity of ordering colours, which indicate the proficiency grades, the so-called belts. In the Musado system, the colour of proficiency grades, from the lowest, are: white, orange, yellow, green, blue, brown and black. Almost the same applies to the karate system: white, yellow, orange, green, blue, brown and black. Not only for this reason is the methodological complexity of both systems similar. The Musado system can, on the other hand, increase its “score” by focusing on training with a cold weapon, firearm, rod-shaped objects, field shovels and other equipment typical of police officers’ and soldiers’ jobs. Its downside is the general complexity of the system, which is based on the police and military

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requirements. Candidates' physical and mental resistance is required; exercises on hard surfaces and with real weapons are common; the training imitates real practice as much as possible.

## 4.2 The "Spearing Elbow" Methodological Set in Professional Self-Defence Training for Medical Staff

No comprehensive self-defence system is easy to learn. Beginners have to take tens of intensive training hours to master a number of basic physical actions. Further improvement involves months of hard work depending on motivation, talent, and, especially, time possibilities. Complex training also presents a higher risk of injury, especially for people inexperienced in sport, who may have rather frequent restrictions regarding particular exercises. It is necessary to find other solutions concerning the training of medical staff. In order to find them, it is, first of all, necessary to answer the following questions: What are the goals of the training? What is the most common scene of conflict like? What is the required method of defence?

The aim of the training is to provide tools for addressing model situations into which paramedics repeatedly get. These are mainly situations in the pre-conflict phase, with frequent verbal attacks, entering the personal zone, thus disturbing the safe distance. The most common places of conflict are in the open air and inside ambulances. However, "open spaces" does not mean that there is enough space for defenders to retreat. In the pre-conflict phase, attackers usually shorten the distance, and paramedics often need to make a decision about when they no longer have enough space. The same applies for an ambulance. From this point of view, emergency medical service defenders mainly need means to keep the correct distance and technique tools to protect them at the moment of an attack within the personal zone.

The required method of defence in the case of medical professionals is fundamentally different from police force methods, and does not differ from civil self-defence. The aim of this defence is to avoid aggression and retreat to a safe distance, or to monitor the development of a conflict and let the Czech police deal with it. This implies that a defender's movement actions must aim at de-escalating the tension, and must not be primarily offensive.

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After this basic definition, it is important to narrow the content of the curriculum with the help of multifunctional techniques. This means that one technique can be applied to multiple self-defence situations. The composition of movement actions must, first of all, reflect a logical approach with a preference for easy-to-remember technique procedures. The priority is not to get hurt. This means, among other things, that it is necessary to exclude strikes that are difficult to master and that pose risks of injury even in the training phase. In some respects, these actions can include, for example, strikes with full extension. These strikes are designed to reach over a relatively long distance between defenders and attackers. Their goal is to perform an impact over a long path of movement. For beginning students, however, focusing their upper limb on the target is difficult even with regard to an opponent's potential movement. The segment with the highest speed (standardly a clenched fist) moves over the longest distance from the body and, in combination with ignorance of the correct strike technique, injuries can occur both in training and in real conflicts. Even from a legal point of view, long-distance strikes are to be considered with caution. The reason is that if an attacker has not yet reduced the distance to the level of the personal zone, it is possible to deal with the situation in another way, for example, by retreating. If this is not possible, attackers are probably within the contact/impact distance. In such a case, strike elements for a limited distance are suitable (for defenders) instead of direct or arc strikes with a clenched fist in full extension. In addition, paramedics should always negotiate if it is possible; it would be inappropriate to train paramedics for ring fights. These are no boxing matches, where opponents attack tactically from different, even long distances in order to score points.

A suitable movement action for a course‘s methodological set for a limited space is spearing elbow (SE), whose key element is an elbow strike in a straight line, which is a multifunctional technique for various attack situations. Spearing elbow is a movement action that is based on stance, but can also be applied in non-stance combats. Its basis is gripping the attacker's head with the dominant (negotiating) hand, supporting the head in the area of the forehead and positioning the sharp protrusion of the humerus (olecranon) towards the area of impact. The proposed methodological set is based on the knowledge of one instinctive movement, which is based on people's natural reactions, and represents a potential for a wide range of defensive measures. It is a technique tactical element, which is

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Figure 68. Correct communication distance vs contact distance
Figure 69. Spearing elbow from the right and left side

based on a wide group of movement actions of elbow strikes and can thus be combined with other variants, such as arc-type strikes.

Spearing elbow has technical, biomechanical and, above all, tactical advantages.

- High combat potential, given the small and hard impact area of the hard edge of the humerus (olecranon).
- Simplicity of its design due to natural reflexes associated with face protection.
- Accuracy given by half the range of strike motions, which reduces possible deviations of the strike trajectory.
- Possibility of active defence, given its impact potential.
- Possibility of passive defence given by the position of the elbow at the level of the attacker's vital zone.
- Possibility to regulate the combat potential by selecting sensitive points in the impact area (face, collarbone, pectoral muscle) and choosing a static stance or overstep.
- Possibility of defence against several variants of attack:

    1. Defence against strike
    2. Coordination with other tactical elements – communication attitude
    3. Coordination with other technical elements – defence against attempted grip

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4. Coordination with vital points on the body and control of distance in the personal zone
5. Defence against attempted throttling, strangulation or strike
6. Active defence – strike in a straight line
7. Active defence – strike in an arc line
8. Active defence – combination of strikes

Figure 70.

**1. Defence against strike**

Attackers perform offensive arc strike actions with an open palm. SE actions are used as a cover.

Figure 71. a, b

**2. Coordination with other tactical elements – communication attitude**

This movement pattern is hidden in the tactical action of the communication attitude.

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Figure 72. a, b, c

**3. Coordination with other technical elements – defence against attempted grip**

Attackers perform offensive actions by gripping the opponent's arm. Defenders use the technique of getting out of the grip and going immediately over to a passive SE.

**4. Cooperation with vital points on the body and control of distance in the personal zone**

The attacker performs an offensive action in the form of a slow shortening of the walking distance towards the partner. The defender uses the passive SE to maintain distance. Its effect is increased by targeting vital points: the face, the collarbone and the chest muscle.

Figure 73. a, b, c

**5. Defence against attempted throttling and strangulation**

Attackers perform offensive actions in the form of strangulation. Defenders use defensive actions for the transition to a passive SE.

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Figure 74.

**6. Active defence – strike in a straight line**
The effect of striking actions can be supported by moving out of stance or by overstepping.

Figure 75.

**7. Strike in a straight line**
Active defence – strike in an arc line
Attackers block a defender's elbow in a straight line. Defenders strike with the elbow of the other limb in an arc direction.

**8. Active defence – combination of strikes**
Defenders apply a combination of strikes with a change of stance (two strikes in the frontal stance with overstep, one strike with transition to the lateral stance).


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Figure 76. a – here the SE is used as a cover, b – the cover helps in retreat, c – active defense by the spearing elbow when the rescuer is knocked down)

### 9. Non-stance combat

The above overview of movement possibilities is not final. The methodological set for SE physical action offers more ways of extension, especially in other types of stances. In non-stance combat, where a healthcare professional may be attacked by a lying patient during a specialist procedure, the defensive part of the action may be advantageous. This protects paramedics during their retreat.

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# Conclusion

The main goal of this publication is the prevention of injury risks during the teaching in courses of professional self-defence for secondary school and university students, with a focus on professional self-defence courses for medical staff. Selected biomechanical contexts associated with physical actions in combat systems can, together with proposals for methodological procedures, broaden knowledge horizons of both teachers and their students. Teachers who know the biomechanical background of self-defence techniques also have a better understanding of mechanisms of injuries to the human body and are able to effectively apply prevention tools in teaching. However, this is not the only key to successful training. Being a knowledgeable biomechanic does not mean being a good teacher.

Teaching of combat systems is unique in comparison with other study courses. It is perhaps one of the oldest types of knowledge transfer from generation to generation from the very beginnings of mankind. Until recently, all combat systems were part of preparation for combat and were strongly conditioned by the aggressive instincts of human beings. The original task was not relaxation, social prestige, joy of movement or making money, as is often the case now; the goal was, above all, preparation of warriors for battle, or improvement of hunting skills. The philosophy of traditional martial arts, which underwent great evolution during the modernization of Japan, shows a different path, which is compromise, harmony and love. The aims of teaching differ depending on whether sports, arts or self-defence systems are taught. Yet, the ethical aspect should be included in the teaching of every system to the same extent. The martial arts system accentuates the importance of rules and the sense of fair play associated with competitive activities. In martial arts, the ethical aspect is conditioned by the historical legacy, especially the Bushido Code. In the self-defence system, it is the legal interpretation of necessary defence that matters now. Teachers must be able to delicately interconnect everything into one whole. From the point of view of required outcomes of teaching professional self-defence, the priority is not to train future professional

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combat athletes, but professionals who can think tactically and can quickly and correctly decide on a specific solution with minimal consequences for both parties.

Self-defence teachers must first and foremost be "psychologists" with the ability to estimate people. By teaching combat techniques, teachers put potentially abusive tools in their students' hands. This is where teachers' most difficult task lies. When teachers stand, in the dojo, in front of their students, they do not just face the students. Together with students physically present in a lesson, there are all their ancestors from the timeline of human history, where all the positive and less positive elements of human behaviour are in one place in quantum superposition. Teachers should know about these multitudes of beings and try to work with them all. The nature of human behaviour is based on phylogenetic circumstances. The direction in which the first human societies developed was strongly determined by the instinct of aggression. It is rooted deep in human beings as a defence mechanism and is innate in man (119). Aggressive behaviour can be a tool for meeting personally important needs. The societal climate also contributes to aggression, and the socio-cultural pattern of behaviour that represents a given society plays an important role. When, in the past, aggressive behaviour was beneficial for particular groups of people, these strengthened it and passed it on to future generations. Why do human beings behave like that? It is important to understand the importance of people being aware of the difference between their own group and strangers, which conditioned humans from the beginning. Distinguishing these two allowed people to orient themselves effectively. Strangers posed a danger, and therefore it was necessary to defend against them. *"...people tend to divide other people around them into close, i.e. friendly people, and strangers, who are, at best, accepted neutrally. People have a general tendency to distrust any difference and to address problems of potential threat by increased readiness for aggressive actions aimed at strangers"* (119). As humankind was motivated, throughout phylogenesis, by a strong need to survive, they tested their tendency to aggressive behaviour, which seemed to be efficient and effective.

Human phylogenesis has lasted 3 million years, and 99 % of this period was the Paleolithic period. Only 1 % (30,000 years) was the period of developed empires. With a certain exaggeration we can say that our brains still largely live in "caves" and orient themselves in the surrounding area

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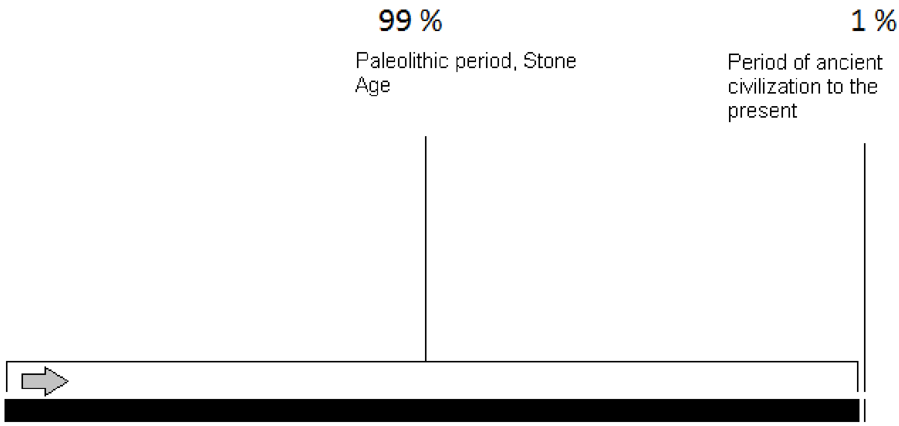


Figure 77. Wide timeline

according to the rules that were in place over hundreds of thousands of years. Our bodies look different, technology has changed the environment around us, but the basis of mankind is still the same, whether these are character traits, virtues, the combination of love and hatred or the desire for vital resources. From the point of view of teaching, it is important to notice students' emotions. Teachers should be able to anticipate emotions in their students and control emotions according to the recommendations of a well-known martial arts teacher:

> *"Martial arts instruction is not muscle training, but emotion training"*
> (Bruce Lee).

Students in classes can resemble waves. Their behaviour and living experience is not static, but dynamic. In everything they do, they reinforce each other at certain points, and, at other points, they interfere with each other, colliding and influencing each other. Individual waves can also intertwine and be reflected in collective characteristics. Experienced teachers know moments when teaching is difficult; their students behave differently for no apparent reason. Some days simply seem to attract problems, others do not. It is possible to trace a certain collective interconnection where a group behaves as if they were one individual; it is, however, not yet clear and we do not know with certainty how these mechanisms actually work. Students, in their cognitive world, are in multiple states of mind at the

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same time; this is especially true for the younger generation. This, to some extent, is supported by the activity of the hormonal system, which can affect the tense environment of combat training. Teachers should be alert to their surroundings, because only in this way can they be fully immersed in the reality and able to anticipate and prevent a number of problems. However, they cannot describe and entirely understand all the mechanisms and states of mind that occur in students at the current moment. Inside human thought, the past, the present, and the future probably merge into one moment, and time is not lived and interpreted as usual. Individuals act on the basis of their experience from the past, are inspired and activated by the present moment and, at the same time, try to imagine and grasp possible future consequences of their actions in the form of various assumptions, ideas and estimates. Reading data from this imaginary set of information is a problem. States of thought are hidden deep within human minds. At the moment of their detection by another person, the system shows these states in a limited form, which is still understandable for the standard human thinking potential. The moment the macro-world demands revealing the results of an individual's thought, the collapsing system creates a positive or negative evaluation.

Most educators tend to perceive their students' behaviour as good or bad. But that does not mean that their perception reflects the true reality about the complex personality of an individual. It may also happen that teachers receive exactly the information they expect: those whose attitude towards students is rather negatively set usually encounter worse manifestations of their students and vice versa. Teachers can interpret students' behaviour either as disruptive, undisciplined and unwilling, or motivating, diligent and inspiring. Superposition, interconnectedness and interference are concepts and notions that are not yet part of the fields of education/pedagogy and psychology, but the world around us is changing very quickly. Likewise, social sciences do not include mechanics, which describes six degrees of freedom for a body in space. Students are also such bodies, and it is necessary to give them some degrees of freedom despite the need for some control in classes. Freedom allows the onset of inner motivation, which is key in the development of each individual. As a rule, teachers have to take some freedoms away from students; this includes various rules, disciplinary measures, strict interpretations of techniques with one possible correct implementation and the like. But when teachers take away all six freedoms, "shifting and rotating on all the X, Y and Z axes", there is

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a risk that something will crack. This happens even with the strongest material in the world and in any interpersonal relationship. It does not matter what kind of relationship it is: whether it is a relationship between teacher and student, a relationship between man and woman, a relationship between colleagues at work. Students are constantly developing, even within very short time horizons. After only a few lessons, it is possible to observe students' changes in their approach to individual tasks and to the whole group. Students, in turn, impact their teachers, who are also undergoing their own "evolution". In a broader perspective, combat systems, too, are constantly evolving, and thus remind one of independent living entities. Probably in the whole universe, whether we are able to measure it or just realize it, changes are constantly taking place; we change in these changes and we have to change in them just as water changes the shapes of stones over which it flows. The Romans describe it as:

> *"Temporamutantur et nos mutamur in illis – Times are changing, and we are changing with them".*

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# Thanks

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Figure 78.


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# Supplementary material

Table 6. Summary of the included studies which reported the biomechanical characteristics of upper limb strikes.

| Author | Participants n, (gender); age ± SD (y); height ± SD (m); BM ± SD (kg); experiences; specificity | Main aim | Measured parameters | Main result |
|---|---|---|---|---|
| de Souza et al., 2017 | 8 (male); 20.25 ± 4.13; 1.74 ± 0.04; 72.41 ± 9.62; professional; level of black belts with expertise 7.64 ± 4.33 y | Analyzed maximum impact force, relationship between anthropometric(age) and biomechanical variables with the maximum impact force. | Reverse punch (Gyaku Zuki) | Fmax 2314.5 N<br>Fmean 1812.0 N |
| Chiu et al., 1999 | 12 (8 males, 4 female); (N/R); (N/R)1.69; (N/R) 64.40; (N/R); The ROC National Karate Team for the 1998 Bangkok Asian Games | Analyzed reaction time, attacking speed and punch force in karate punch. | Reverse punch (Gyaku Zuki) | vmean 14.7 m/s<br>gmean 57.4 g |
| | | | Straight punch (Oi Zuki) | vmean 10.6 m/s<br>gmean 57.7 g |
| Gianino et al., 2010 | High School students (N/R for all) | Analyzed the kinematics and dynamics of karate techniques. | Reverse punch (Gyaku Zuki) | amax 63.0 m/s/s<br>vmax 13.0 m/s |
| | | | Straight punch (Oi Zuki) | amax 49.0 m/s/s<br>vmax 10.0 m/s |
| Daniel et al., 2014 | 10 (male); (N/R) 21–23; (N/R) 1.68–1.84; (N/R) 63–86; (N/R); Karate athletes | Analyzed influences plantar pressure and the execution speed. | Reverse punch (Gyaku Zuki) | vmean 8.2 m/s |
| | | | Kizame Zuki | vmean 6.8 m/s |


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| | | | | |
|---|---|---|---|---|
| Rinaldi et al., 2018 | 9 (7male, 2 female); 22.90 ± 8.90; 1.72 ± 10.80; 64.50 ± 9.60; professional; Karate athletes from the 2 to the 5 dan | Analyzed kinematic, kinetic and electromyography characteristics. | Jun Zuki | Fmean 181.2 N |
| Cesari et al., 2007 | 12; 30.50 ± 6.0;(N/R); (N/R); mix; Karate athletes 3 dan (n=6) with years of practice 21 ± 5; novice (n = 6) | Analyzed the center of pressure and kinematics of the upper limb for different skill levels. | Tate Zuki | vmax 7.8 m/s<br>vmean 6.5 m/s |
| Bolander et al., 2009 | 13 (10 males, 3 female); (N/R); (N/R); (N/R); (N/R); Moy Tung Ving Tsun martial artist | Analyzed the relationships between accelerations and force under different striking conditions. | Kungfu punch | Fmean 736.0 N |
| Neto et al., 2009 | 13 (10 males, 3 female); (N/R); 1.69 ± 0.01; 68.40 ± 7.30; (N/R); Moy Tung Ving Tsun martial artist | Compare force, precision and reaction time of two punches. | Kungfu punch<br><br>Palm strike | Fmax 1226.0 N<br>Fmean 837.0 N<br><br>Fmax 1549.0 N<br>Fmean 930.0 N |
| Walilko et al., 2005 | 7 (male); (N/R); (N/R); (N/R) 48–109 kg; professional; Olympic boxers | The biomechanics of the head for punches and the risk of head injury. | Straight punch (direct) | Fmax 4741.0 N<br>Fmean 3427.0 N<br>vmax 13.4 m/s<br>vmean 9.1 m/s<br>gmean 58.0 g |
| RatTong Iam et al., 2017 | 3 (male); (N/R) 22–24; 1.63 ± 7.00; 60.57 ± 3.93; professional; Muai Thai champions | Analyzed the role of trunk rotation in straight punches. | Straight punch (direct) | Fmax 1605.0 N<br>Fmean 1323.3 N<br>vmax 6.6 m/s<br>vmean 6.3 m/s |
| Loturco et al., 2016 | 15 (9 males, 6 female); 25.9 ± 4.7; 1.72 ± 0.10; 64.56 ± 12.10; (N/R); Amateur boxers athletes | Analyzed the relationship between punching impact and strength and power variables. | Straight punch (direct) | Fmean 1152.2 N |
| Chadli et al., 2014 | 11 (male); 23.50 ± 0.50; 1.79 ± 0.01; 77.36 ± 11.06; (N/R); Amateur box athletes | Present a punch analysis tool for boxers. | Straight punch (direct) | Fmax 1162.0 N<br>Fmean 989.0 N<br>amax 296.0 m/s/s<br>amean 258.0 m/s/s<br>gmean 30.2 g |
| Busko et al., 2016 | 48 (21 males, 27 female); 17.30 ± 1.60; 1.72 ± 5.85; 66.10 ± 10.35; (N/R); Boxers and taekwondo athletes; | Analyzed punching and kicking forces and reaction time. | Straight punch (direct) | Fmean 1592,5N |

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| | | | | |
|---|---|---|---|---|
| Bružas et al., 2015 | 8 (male); 22.30 ± 2.50; 1.79 ± 0.06; 71.70 ± 9.60; (N/R); Amateur box athletes | Analyzed the effects of a 4-week cycle of plyometric training with external weights on punching ability. | Straight punch (direct)<br>Said punch<br>Low punch | mmax 300.0 kg<br>mmax 300.0 kg<br>mmax 400.0 kg |
| Halperin et al., 2017 | 13 (male); 25.00 ± 5.00; (N/R);74.00 ± 10.00; (N/R); Elite and amateur kickbox athletes | Analyzed whether giving the athlete a choice over the order of punches would affect punching velocity and impact force. | Straight punch (direct) | Fmax 3000.0 N<br>vmax 14.0 m/s |
| Halperin et. al., 2016 | 15 (7 males, 8 female); 26.00 ± 3.00 (N/R); 69.00 ± 9.00; mix; intermediate competitive boxers and kickboxers | Analyzed the effects of different instruction on punching. | Straight punch (direct)<br>Said punch | *2.5 N/kg<br>*3.1 N/kg |
| House et al. 2015 | 22 (17 males, 5 female); 23.55 ± 3.20; (N/R); (N/R); novice; (N/R) | Analyzed factors that contribute to the impact force of punch. | Straight punch (direct) | Fmax 475.2 N<br>Fmean 238.7 N<br>vmax 8.1 m/s<br>vmean 7.0 m/s |
| Dyson et al., 2005 | 6 (male); 24.60 ± 3.30; 1.82 ± 0.05; 73.30 ± 19.00; (N/R); competitive amateur boxers | Analyzed the punch force of straight punches. | Straight punch (direct) | Fmax 4236.0 N |
| Cheraghi et al., 2014 | 8 (male); 20.40 ± 2.10; 1.77 ± 8.50; 70.40 ± 16.80; professional; elite amateur boxers | Analyzed biomechanical parameters of head, upper and lower body extremities during a straight punch. | Straight punch (direct) | vmax 9.4 m/s<br>vmean 7.8 m/s |
| Bingul et al., 2017 | 9 (male); 19.33 ± 2.11; 1.74 ± 3.79; 66.00 ± 6.62; professional; elite boxing athletes | Analyzed the effects of impact force and kinematics indicators in boxing for different stance. | Straight punch (direct) | Fmean 1987.4 N<br>amean 424.6 m/s/s<br>vmean 5.3 m/s |
| Kimm et al., 2015 | 16 (10 males, 6 female); (N/R) 27; 1.74 ± 24.00; (N/R); mix; boxers with varying levels of experience | Analyzed hand speed during the direct punch. | Straight punch (direct) | vmean 8.1 m/s |
| Pierce et al., 2016 | 12 (male); (N/R) 18–36; (N/R); (N/R) 59.0–99.8; professional; boxers | Analyzed punch force in professional boxing matches. | Straight punch (direct) | Fmax 5358.0 N<br>Fmean 1149.0 N |

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| | | | | |
|---|---|---|---|---|
| Svoboda et al., 2015 | 1 (male); (N/R); (N/R); (N/R); (N/R); Taekwondo sportsman | Analyzed impact force for straight punch. | Straight punch (direct) | Fmax 2292.0 N<br>Fmean 2151.0 N<br>vmax 8.4 m/s<br>vmean 8.0 m/s |
| Smith, 1983 | 15 (male); 24.90 ± 6.40; 1.73 ± 7.75, 72.85 ± 12.50; mix; 5 white belt, 5 green belt, 5 black belt Karate athletes | To determine the comparative effects on fist velocity and resultant momentum of a heavy bag when punched by different skill level subjects wearing no glove and different types of gloves. | Straight punch (direct) | vmean 11.5 m/s |
| Atha et al., 1985 | 1 (male); (N/R); (N/R); (N/R); professional; boxing athlete Franko Bruno | Analyzed velocity on impact and peak force for punch. | Straight punch (direct) | Fmax 4096.0 N<br>amax 90.0 m/s/s<br>vmax 8.9 m/s |
| Čepulénas et al., 2011 | 10 (male); 22.50 ± 3 .38; 1.79 ± 7.70; 71.87 ± 15.18; professional; elite boxing athletes | Analyzed the impact of the physical training sessions on the changes in the indices of athletes' fitness. | Straight punch (direct)<br>Side punch<br>Low punch | mmax 253.0 kg<br>mmax 297.0 kg<br>mmax 303.0 kg |
| Neto et al., 2012 | 7 (4 males, 3 female); 27.00 ± 6.00; (N/R); (N/R); (N/R); Kung fu martial artist | To investigate differences between dominant and non-dominant palm strikes with different stances. | Palm strike | Fmax 1883.6 N<br>Fmean 1706.1 N<br>vmax 5.8 m/s<br>vmean 5.5 m/s |
| Neto et al., 2008 | 13 (male); 23.50 ± 6.10; 1.71 ± 0.08; 67.80 ± 4.74; mix; Yau Man Kung fu athletes with different experiences | Analyzed force, power and efficiency of palm strike by both practitioners. | Palm strike | Fmean 355.0 N |

Fmean = mean force characterizing impact measured during the strike, Fmax = peak force characterizing impact during strike;
vmean = mean impact velocity of the upper limb during the strike, vmax = peak impact velocity of the upper limb during strike;
amean = mean impact acceleration of the upper limb during the strike, amax = peak impact acceleration of the upper limb during strike;
gmean = mean gravity acceleration of the target/head form measured during the strike;
mmax = max effective mass of the strike / effective mass of the upper limb measured during the strike;
* = mean normalized to body mass impact force;
(Beranek et al., 2020)


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Table 7. Biomechanical tolerance of different regions/bones of the skull – contact force required for fracture

| region bone | study | force tolerance (kN) | force tolerance (kg) | impact area (cm²) | N mm⁻²/ MPa | weight (kg) | velocity (m·s⁻¹) |
|---|---|---|---|---|---|---|---|
| Frontal (forehead) | Schneider and Nahum (1972) | 4.0–6.2 | | 6.5 | | 1.1– 3.8 | 3–6 |
| | Advani et al (1975) | 4.0–6.2 | | 6.45 | | 9.1 | 5–10 |
| | Nahum et al (1968) | 4.0–6.2 | | | | | |
| | Voigt and Thomas (1974) | 5.5 | | | | | |
| | Allsop et al (1988) | 2.2–6.4 | 224–662 | | | | |
| | Gadd et al (1968) | | 498 | | 7.58 | | |
| | Tarriere et al (1981) | 7.7 | | | | | |
| | Hodgson (1967) | 4.6–8.7 | | | | | 2.5–3.3 |
| | Cormier et al (2011) | 2.5–7.6 | | 6.45 | | 3.2 | |
| Temporo-parietal | Nahum et al (1968) Allsop (1991) | 2.5–5.2 | | 6.45 | | | |
| | Advani et al (1975) | 5.7 | | | | 9.1 | 5–10 |
| | Hodgson (1967) | | 159–454 | | | 0.9–7.2 | 4 |
| | Gadd et al (1968) | | 249 | | | | |
| | Raymond et al (2009) | 5.9 | | 38.1 mm projectile | | 0.10 | 18–37 |
| | Hodgson and Thomas (1971) | 5.5 | | | | | 1.6–4.7 |
| | Hodgson (1967) | | | | | | |
| Lateral region | Schneider et al (1972) | 2.0–3.6 | | 6.5 | | 1.1–3.8 | 3–6 |
| | Nahum et al (1968) | 2.0–3.6 | | 6.45 | | | |
| | Allsop et al (1988) | 5.2 | | | | | |
| | Yoganandan et al (2003) | 5.5–9.9 | | 5 | | | 4.8–7.7 |
| Occipital region | Advani et al (1982) | 12.5 | | | | | |
| | Allsop (1991) | 12.5 | | | | | |
| | Hodgson (1967) | 15.9 | | | | | 3.7 |
| | Stalnaker et al (1977) | 7.1 | | 15.2 cm diameter | | 10 | 6.8–7.2 |

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|---|---|---|---|---|---|---|---|
| Os zygomaticum | Advani et al (1982) | 1.0 | | 6.45 | | | |
| | Nahum et al (1968) | 1.0 | | | 1.38–4.17 | | |
| | Nyquist et al (1986) | 0.4 | | 2.54 | | | 2.7–7.2 |
| | Hodgson (1967) | | 159–454 | 2.54–13.2 cm diameter | | 0.9–7.2 | 4 |
| | Gadd et al (1968) | | 225 | | | | |
| | Allsop et al (1988) | 0.8–2.4 | 90–244 | | | | |
| | Yoganandan et al (1991) | 1.1–1.3 | | | | | 4 |
| | Gallup (1988) | 3.2–3.8 | 335–394 | | | | |
| Mandibula | Nahum et al (1968) | 1.4 | | 6.45 | | | |
| | Hodgson (1967) | | 159–454 | 2.54–13.2 cm diameter | | 0.9–7.2 | 4 |
| | Nyquist et al (1986) | 0.6 | | 2.54 | | | 2.7–7.2 |
| | Schneider and Nahum (1972) | | | | 2.76–6.20 | 1.1–3.8 | 3–6 |
| Os nasale | Nyquist et al (1986) | 0.3 | 306 | 2.54 | | | 2.7–7.2 |
| | Hodgson (1967) | | 159–454 | 2.54–13.2 cm diameter | | | 2.5–3.7 |
| | Gallup (1988) (nasal area) | 1.9–2.9 | 200–299 | | | | |
| | Swearingen (1965) | 0.3–4.5 | | | | | |
| | Nahum et al (1968) | | | | 0.13–0.34 | | |
| Maxilla | Nahum et al (1968) Advani et al (1982) | 0.7–1.5 | | 6.45 | | | |
| | Nyquist et al (1986) | 1.4 | | 2.54 | | | |
| | Hodgson (1967) | 0.6–1.8 | 159–454 | 2.54–13.2 cm diameter | | | |
| | Allsop et al (1988) | 1.0–1.8 | 102–184 | | | | |
| | Nahum et al (1968) Schneider and Nahum (1972) | | | | 1.03–2.07 | 1.1–3.8 | 3–6 |

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