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Restytucja wielkości cech postawy w płaszczyźnie czołowej po obciążenia masą transportowanych przyborów szkolnych w trybie ciągu lewą i prawą ręką uczniów obojga płci w wieku 7 lat

Restitution of the size of postural features in the frontal plane after loading with the weight of school items carried with the right and left hand in 7-year-old pupils of both sexes

Ocena postawy ciała gimnazjalistów w kontekście ich aktywności fizycznej

Assessment of body posture of junior high school students in the context of their physical activity

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Biotensegration of malocclusion and temporomandibular disorders with diseases of the musculoskeletal system and posture defects – a literature review, supported by own observations

Biotensegracja wad zgryzu i zaburzeń czynnościowych stawów skroniowo-żuchwowych z chorobami narządu ruchu i wadami postawy – przegląd piśmiennictwa poparty obserwacjami własnymi

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Abstract
Although it enables a quick evaluation, medical diagnostics of the human myofascial-skeletal system is not always used to its full capabilities. This often hampers the objective assessment of a dysfunction and limits treatment options. Dysfunctions of the stomatognathic system, of different aetiology, are becoming more prevalent. Many scientific studies are in to relationships between organs and systems of the human body that can cause dysfunctions of the temporomandibular disorders. Studies investigating correlations between a myofascial-skeletal disorder and temporomandibular disorders are to be found in the literature. To achieve a good understanding of aetiology of these dysfunctions, a holistic view of a patient is advisable, which takes into consideration the fact that the temporomandibular joint is an integral part of the whole body. This study is a review of the literature, supported by own examples on investigating the relationship between myofascial-skeletal disorders and a temporomandibular disorder, which, in the light of current medical knowledge, is attributed to the phenomenon of biotensegrity. A conclusion has been put forward on the basis of 136 scientific reports that a dependency exists between the said dysfunctions.

Keywords
biotensegrity, disorders of the musculoskeletal system, posture defects, dysfunctions of the masticatory system, temporomandibular joint disorder

Streszczenie
Diagnostyka medyczna układu mięśniowo-powięziowo-szkieletowego człowieka, choć umożliwia szybką ocenę, nie zawsze jest w pełni wykorzystywana. Utrudnia to często obiektywną ocenę dysfunkcji i ogranicza możliwości leczenia. Coraz powszechniejsze stają się dysfunkcje układu stomatognatycznego o różnej etiologii. Wiele badań naukowych poświęconych jest związkom między narządami i układami organizmu człowieka, które mogą powodować dysfunkcje w obrębie stawów skroniowo-żuchwowych. W literaturze można znaleźć prace badające korelacje pomiędzy zaburzeniem mięśniowo-powięziowo-szkieletowym a zaburzeniami skroniowo-żuchwowymi. Dla dobrego zrozumienia etiologii tych dysfunkcji wskazane jest całościowe spojrzenie na pacjenta, uwzględniające fakt, że staw skroniowo-żuchwowy jest integralną częścią całego organizmu. Niniejsza praca jest przeglądem piśmiennictwa, popartym własnymi przykładami, dotyczącym badania związku zaburzeń mięśniowo-powięziowo-szkieletowych z zaburzeniem skroniowo-żuchwowym, które w świetle aktualnej wiedzy medycznej przypisuje się zjawisku biotensegracji. Na podstawie 136 doniesień naukowych wysunięto wniosek, że istnieje zależność między tymi dysfunkcjami.

Słowa kluczowe
biotensegracja, zaburzenia narządu ruchu, wady postawy, dysfunkcje narządu żucia, zaburzenia stawu skroniowo-żuchwowego

Introduction

Disorders of the musculoskeletal system

Musculoskeletal complaints are one of the commonest health issues, which comprises a vast range of medical problems and thus they affect millions of workers reporting pain in the joints, spine and muscles [1–4]. Pains resulting from musculoskeletal disorders (MSD) are caused by are caused by tension disorders in myofascial structures, changes in osteoarticular structures and neurological problems, etc. Consequently, lead to the loss of overall ability and a deterioration in the quality of life. MSD usually affect the neck (the cervical section of the spine), back of the neck, shoulders and lower limbs [5–13]. They can also relate to the pain of the back (especially the lower back), lower limbs, feet, caused by chronic strain of the organism [14–22]. They can be provoked by injuries (including chronic overload injuries) and be the result of systemic diseases affecting the condition of the musculoskeletal system [23–26]. Starting as slight pains, these health problems transform into severe dysfunctions that often lead to partial disability. External factors contributing to MSD may be: the type of work performed (both sedentary and heavy physical activity), physical activity and a number of individual factors (weight, posture defects, improper lifestyle) [27–46]. Most MSD develop over time. It is often difficult to find one particular cause of the disorder, and the inducing factors may be varied [47]. For example, there are many indications that deformations and degeneration of the spine, and consequently the significant pain caused, are a consequence of undetected posture defects in young people [48,49], whose only symptom is the visual asymmetry of the body, with an absence of visible symptoms [50] and motor activity [51, 52].

Periodic and screening diagnostics should be carried out on an individualized manner, especially in relation to the patient's age [53–55]. The total development of the posture function takes place at the age of about 11–12 years, and remains stable until approximately 65 years of age [56]. Consequently, the conclusion should be based on the assessment of the entire posture, taking into account, in particular, the structural integration (the so-called tensegration) of all the elements of the locomotor system, without neglecting the visceral tissue. An important aspect of postural evaluation is also the examination of balance, which is carried out with a pedobarograph [57]. The essence of postural defect prophylaxis is periodical and requires the full evaluation of the posture, walking pattern and compensation mechanisms [58–60]. The detailed diagnosis in clinical conditions of spinal curvature in the three-plane view, assessment of shoulder asymmetry in relation to the hips, the examination of mobility ranges (bend, straightness, etc.), and evaluation of gait are recommended [61]. In addition to the assessment of global patterns, the entire body posture should also be assessed segmentally, i.e. lower limbs, pelvis, trunk (including the spine), shoulder position, head (including craniofacial), upper limbs. [62]. However, the assessment of the causes of defects and deformations should not be neglected, differentiating the problems originating from the osteoarticular, muscular and nervous systems [63,64], taking into account systemic diseases and the patient's weight. The human posture consists of a position in space and aims to keep the body in balance, both while standing and while locomotion. It is an involuntary process, maintained by skeletal muscle contraction, coordinated by stimuli and neuromuscular regulation. It is functional when all systems are in harmony with the so-called kinetic chains, which are painless, and with a correct relationship of the individual body segments in three planes. Thus, a body that is not in structural equilibrium would be characterized by imbalance and consequent pain [65, 66].

The stomatognathic system, together with the maxilla and mandible, take an active role in maintaining the correct position of the skull with the help of the neck flexors and extensors, the hyoid, masticatory, as well as shoulder girdle muscles. It has been demonstrated that mandible activity changes the electrical capacity of the postural muscles, i.e. vertebral, temporomandibular, cervical spine and shoulder girdle [67–69]. Malocclusion and weakening of the oral cavity muscles may lead to changes in the frontal and sagittal position, which may result in scoliosis or apparent asymmetry of limb length. An imbalance of masticatory muscles disrupts the kinematic chain of the oral cavity and changes the posture, affecting pain in the lower back. The relationship between dental occlusion is justified by functional and anatomical compounds of the masticatory system and the process of body balance regulation [70, 71]. Unconscious postural reactions are associated with nociceptive reflexes resulting from contact between tooth surfaces [72, 73]. It has been frequently indicated that dental braces do not prevent the progress of spinal curvature in adolescents as well as deformities in adults [74–79]. The direct relationship between the masticatory organ and the cervical segment of the spine is not questionable. Cervical and occipital pain is considered to be the next major challenge for the global civilization [80–86]. Positioning the head in protraction (FHP – Forward Head Posture) was defined as an epidemic concern of modern times. The forward movement of the head through biokinematic compounds causes a change in the center of gravity of the body. The shoulders are positioned in protraction, thoracic kyphosis and lumbar lordosis will deepen. The pelvis is tilted anteriorly. As a consequence, the position of the lower limbs changes [87–97]. The curve of the spine stabilizes about 5–6 years after the proprioreceptic maturation of the feet. The spinal-foot system maintains balance and provides support and resistance to pressure forces [98–101]. Considering civilization's growing problem of spinal defects and pain, its relating consequences on the feet should also be considered. The problems of scoliosis effects on lower extremities and gait have been repeatedly analysed by means of pedobarography, which showed significant effects on the distribution of pressure within the feet. [102–104]. The axial imbalance of the spine affects the asymmetric distribution of the body's equilibrium during standing and walking, which may affect the development of malformations in the lower parts of the body through long-lasting compensating and destabilizing processes [105–107]. In the screening diagnostics of body posture, the use of pedobarography is justified, particularly in the evaluation of posture in terms of tensegrity (examination of balance, gait, etc.) [108]. It would be deemed logical to conclude that the assessment of posture should also take into account the ascending problems, which in this case would be the impact of

foot defects and dysfunctions on the parts of the upper body.
Diseases of the musculoskeletal system often are chronic and stable. Musculoskeletal pains, depending on their localisation, are divided into generalised and local, depending on their duration, into acute and chronic, and depending on the cause, into primary and secondary. Clinically, it is important to differentiate disorders manifested by musculoskeletal pain into inflammatory and non-inflammatory [109]. This allows for a correct diagnosis of the nature of the basic pathological process causing the ailments [110, 111]. The risk of the development of musculoskeletal disorders also increases in the circumstances of operating psychosocial factors, such as time pressure, low level of job satisfaction, lack of [the feeling] of being in control under the condition of high requirements, or inadequate social support [112]. Many authors assume modifying the influence of the psychosocial factors of work on the development of overuse syndromes caused by physical factors. Meanwhile, many occupational factors (e.g. repetitiveness of work tasks, work pace, no rest breaks, etc.) serve as a proof of poor control over working conditions and may be themselves an independent factor of overuse syndromes' development. Stress caused by psychosocial factors may affect human health in two ways that differ in the mechanism and pace of change [113]. The instant path that comprises biological changes taking place in the organism while under stress, whereas the delayed path relates to all fixed changes in the psyche and behaviour of an individual due to cumulative effects of the instant changes in somatic, psychological and behavioural processes. The instant path plays a major role in the development of musculoskeletal disorders. It comprises important changes in the organism such as an increase of catecholamines and cortisol secretion, increase of heart rate activity and skeletal muscles tension, including the neck and back of the neck muscles [114–117]. The following individual characteristics such as age, female gender (number of pregnancies, taking oral contraceptives, menopause, hormone replacement therapy), obesity, low overall physical activity, smoking and alcohol abuse, as well as the following diseases: diabetes mellitus, thyroid insufficiency and rheumatoid arthritis should be taken into consideration while discussing risk factors of musculoskeletal disorders [118–120]. Non-occupational overuse, a type of sport or a hobby constitute another group of factors. Fibromyalgia, whose main characteristic is generalised pain of the musculoskeletal system, should be taken into consideration in differential diagnoses of overuse syndromes. In accordance with the criteria set out by the American College of Rheumatology, fibromyalgia is diagnosed when the pain in many parts of the body lasts at least 3 months and the pain upon compression force is at least 11 out of 18 of the so-called trigger points [121].
The complexity of the problem of myofascial pain has a direct impact on the use of therapeutic methods. Only in the initial phase of pain, releasing techniques are used to relax the tissues, focused on the local problem. A number of physiotherapeutic treatments are implemented, applicable in the course of inflammation, neuralgia, increased tension, i.e. electrotherapy, magnetotherapy, cryotherapy, sonotherapy, thermotherapy, etc. [122–128]. However, taking into account the tensegrity relationship and the dependence in the course of bio-kinematic chains, many research and scientific works indicate the need to use integrated therapy methods. They mainly include manual techniques to increase functionality of the musculoskeletal structures as well as the whole organism (structural integration). One of the methods of holistic therapy of the musculoskeletal system is (OMT), which includes a range of manipulations, muscle energy techniques (MET), visceral techniques and exercising. These methods are applicable both in acute pain and later stabilization of body posture. [129–135]. Manipulation techniques within the joints are widely used in the therapy of acute conditions (such as HVLA-High Velocity Low Amplitude) [136–139], in the treatment of pain the importance of comprehensive therapy in order to unblock joint blocks to restore proper muscle tone has been repeatedly emphasized. Other methods of integrated manual therapy and rehabilitation exercises are: e.g. Kaltenborn-Evjenth method, McKenzie method, S-E-T method, the Mulligan's concept [140–147]. Kinesio Taping (KT) used in the treatment of diseases of the musculoskeletal system, serves sensory and proprioceptive effects, enables the regeneration of places affected by the disease process, giving the effect of improving microcirculation. It has an extremely beneficial effect on microcirculation and the lymphatic system. Improving the functionality of structures [148–166].
Research and scientific works also indicate that the methods of tensegrity therapy take into account neuromobilization. They allow to restore the movability of the nerve in relation to the structures surrounding the nervous tissue. They reactivate the stretching and tensing capabilities of the nervous tissue itself. They should include tissues with pain as well as those that are functionally related to pathology [167–169]. In many countries, acupuncture is one of the methods of integrated therapy of the musculoskeletal system, however, its use still raises many controversies [170–180]. The final therapeutic stabilization of the patient also includes whole-body therapy in most cases. In addition to the previously indicated methods, Yoga, also based on the posture tensegrity model, is often used. In addition to stabilizing the central posture, it also takes into account the effect supporting the psychoemotional state, breathing functions, etc. [181–185]. Stability training for patients with a musculoskeletal disorder reduces pain, instability and prevents setbacks [186–190]. Experiencing pain of the skeletal or muscular system as well as the joints, patients may repeatedly use pharmaceuticals: paracetamol or tramadol, or substances of the non-steroidal anti-inflammatory drugs class (NSAIDs) such as ibuprofen, diclofenac, ketoprofen, metamizole or dexketoprofen [191–194]. The above study of the literature indicates that the key therapeutic approach in the problems of pain in the musculoskeletal system is a holistic therapy that takes into account the biotenegration of the body posture. Therapy based on structural integration is referred to as tensegrity therapy.

Objectives
The aim of this study is to highlight an essential issue, which is a comprehensive diagnosis of functional disorders of the locomotor system of the masticatory system. Additionally, this would entail the need for the inclusion in the clinical assessment of diagnostic procedures of the whole-body posture, the examina-

tion of balance and gait and the process of therapeutic planning, as well as significant elements of the assessment of structural integration. The aim is to also provide the reader with a comprehensive overview, supported by literature and individual clinical cases.

Methodology of meta-analysis

An extensive search of the materials used in this manuscript was conducted online using PubMed, the Cochrane, Medline, Web of Science and EMBASE databases. The results obtained were evaluated and verified for correct qualification by key words. Out of 967 manuscripts, 330 were used in the final concept, including 194 studies which were used in Introduction. The remaining 136 publications were included in the analysis, after assessing their quality.

Main Issue

The term **tensegrity** refers to manual therapy based on structural integration. The first mention of the role of deep fascia in low back pain was made in 1939 [195], while modern medicine has identified it to be one of the main causes on non-injury back pain [196–199]. When tension in the tissue becomes excessive, a damaging stimulus arises. Then, the stimulus is propagated linearly in the human body [200–202]. Hence the conclusion that pain can appear in a place distant from where the pain stimulus first arose [203–207]. This points to the fact that restoring tension of anatomical bands is an indispensable process of rehabilitation and pain therapy, as well as of the restoring of structural integration. This enables the generation of greater force and handling overloading, which results in increased amortisation and help for the muscles that stabilise the spine and are closely linked with a specific fascial band [208, 209]. The concept of fascial bands allows the connections of musculo-fascial lines that influence a dysfunction within the whole posture to be traced. Thereby, including these lines in therapeutic procedures heavily influences the efficacy of the therapy. This holistic approach to the fascial system is based on the still ongoing research into fascial anatomy. A literature study in the area clearly indicates that only a few authors treat the fascia as a three-dimensional system [210]. Nevertheless, it has been repeatedly indicated that manual therapy based on the tensegrity concept (structural integration) is one of the most effective methods of balancing tension within the movement system [211, 212].

Tensegrity (tension-integrity), i.e. structural relationship, where forces are not localised but transferred, which is a theory that attempts to describe experimentally the relationship between musculoskeletal disorders and a dysfunction of the temporomandibular joint. This is a term invented by Buckminster Fuller and Kennet Snelson. The term explains the way the human organism acts as a whole and how the bones of our skeleton, thanks to the tensions of tendons, ligaments and muscles, allow the body to maintain a vertical posture against the force of gravity. In the tensegrity model of the human body, the bones constitute a compression system suspended in the system of constant tensions comprised by the myofascial system. The fascia, which is connective tissue, has a key role. It surrounds the body's organs as a scaffolding, transferring tensions along the fibres [213–216]. In the case of the temporomandibular joint (TMJ), just the joint capsule and capsular ligament transfer signals through the proprioceptive system because the surface of the joint and the mandibular disc per se do not have pain receptors [217, 218]. According to the theory of tensegrity, in the case of excessive tension on the tissue, a damaging stimulus arises that is then propagated linearly along the whole organism. As a result, ailments can appear in a place distant from where the stimulus is operating. According to Still, the fascia constitutes the place in a human body where the causes of diseases can be found, and that the proper fascia functioning guarantees life, whereas its dysfunction leads to the death of the body [219]. Ultrasound examinations revealed that during oscillatory moves e.g. during walking, the fascia often acts as a mechanical energy store [220].

A good body posture is closely linked to an exemplary and healthy musculoskeletal system. It is due to the fact that the posture is a system of points and segments of the body set against each other without any pathological lesions, which guarantee its stabilization and balance at a minimum physical effort and providing optimal static-dynamic efficiency, and ensures the proper development and functioning of the internal organs. Any deflection from a good body posture is called a faulty posture. Faulty postures can be congenital or acquired [221–223]. Congenital body postures may result from metabolic diseases, genetic defects or disorders caused by mechanical, toxic or specific intrauterine factors during foetal development. On the other hand, the acquired result from the body being exposed to the influence of external factors after foetal life, include various diseases of the musculoskeletal or nervous system. The latter include such factors as a sitting lifestyle, unhealthy eating habits and minimal physical activity [224–226]. Implications of bad postures can be clinical or economic, as well as social and societal [227]. Importantly, it should be expected that musculoskeletal disorders will become more prevalent along with a growing number of overweight and obese people in the overall population [228]. Obesity strongly correlates with a higher percentage of bad postures. Unfortunately, according to the WHO data, this is still an upward trend [229–230]. Faulty postures is a broad concept, which includes defects of the skeletal, ligament and muscular system. They may concern the spine, shoulder girdle, chest, pelvis, thigh joints and lower extremities including knee joints, ankle joints and metatarsus [231, 232]. Furthermore, defects per se can be singular or multiple [233–238]. An early diagnosis and prompt adoption of remedial measures in the form of a corrective surgery, kinaesthetic rehabilitation or other physiotherapeutic methods may contribute to the restoration and then strengthening of right patterns of physical activity [239].

Dysfunctions of the masticatory system

The stomatognathic system is a morphological and functional set of tissues and organs of the oral cavity and facial skeleton, which, in its entirety, is the biofunctional system responsible for functions such as masticating, articulating sounds, breathing and expressing emotions non-verbally [240].

It can be divided into the dental and alveolar structure, comprising teeth and the periodontium; a dental and dental syndrome, determining the interrelation between the teeth of the upper and lower dental arch (occlusion, articular states of the mandible); and a musculo-articular structure, comprising the right and left temporomandibular joints (TMJ) and the masticatory muscles. The stomatognathic system is also comprised of the facial skeleton bones, suprahyoid muscles, mimic muscles, the muscles of the tongue and palate, blood and lymph vessels, cranium nerves (i.e. trigeminal, facial, glossopharyngeal, hypoglossal) and salivary glands (including large paired salivary glands: parotid, sublingual and submandibular) [241]. While examining the stomatognathic system of a patient, each dentist takes their history, and performs a physical and additional examination. Particular attention should be devoted to an extra-oral palpation examination, during which anatomical structures such as the muscles: superficial temporal, masticator, sternocleidomastoid, trapezius, deltoid, suprahyoid and suboccipital muscles, as well as the temporomandibular joint should be thoroughly examined. Also, the face symmetry should be analysed, as well as lips' competence, upper airways' patency, extent of the movement of the mandible (including abduction trajectory), acoustics of the temporomandibular joint and the outlet of the trigeminal nerve for neuropathy [242]. Dysfunctions of the stomatognathic system are more prevalent and their aetiology is diverse. Despite being quick, the diagnostics of the masticatory organ dysfunctions is not always used up to its full capability limiting the possibility of obtaining an objective assessment of the dysfunction and relevant treatment options [243]. Many medical specialisations focusing on the treatment of specific dysfunctions have developed, yet a holistic approach to a patient provides an opportunity to choose the right treatment for the patient individually, depending on the pathological condition diagnosed in their stomatognathic system [244]. With regard to the diversity of malocclusions, more and more questions and dilemmas arise about the anatomical structures contributing to the development of these defects.

The specialists should examine the patient's posture, their gait, the way they move, and other individual biomechanical parameters of the musculoskeletal system [245–250]. Many studies are available that have been investigating relationships between organs and systems in the human body that could affect the functioning of the masticatory system. Bringing in the concepts of Anatomy Trains and tensegrity gives even the possibility of linking a dysfunction of the temporomandibular joint to defects in the foot architecture, linking the beginning with the end of the myofascial chain [251]. Patients with dysfunctions of the masticatory system often report ailments in other parts of their bodies, even including those in the joints of the lower limbs and feet [252, 253]. According to the concept of Anatomy Trains, the following anatomical bands can be identified: anterior band, posterior band, spiral and lateral band as well as the deep band. The deep band has a direct connection between the aspect and architecture of the foot and the temporomandibular joint through the following anatomical structures: the tibialis posterior that stabilises the longitudinal and transverse foot arches; the long flexor of the toe that strengthens the foot arches and, additionally, supination (valgity prevention), and their linear connection with the suprahyoid muscles, the mandible and the manubrium, in which the insertion of the sternocleidomastoid muscles is localised [254, 255].

Studies into the relationship between a musculoskeletal dysfunction and a malfunctioning of the TMJ are available in the literature. However, a holistic view of the patient, and paying attention to the fact that the TMJ is an integral part of the whole human body would allow a better understanding of the aetiology of these disorders to be gained [256]. Due to the multiple aetiology of the temporomandibular joint dysfunctions (TMD), the issue remains complex and thus providing the right diagnosis and treatment options is problematic [257, 258]. From the medical point of view, diagnosing patients with the said disorders lies in describing the relationships between distant anatomic structures through transferring forces using soft tissues such as tendons, ligaments, muscles, fascia and the commissure formed by the osseous tissue. The fascia is the most important element in the above system, being connective tissue that passes strains along the fibres [259, 260]. Learning about these relationships will enable a better informed selection of the therapy to provide a long-lasting therapeutic effect.

Patients are more and more often complaining about problems with the TMD to doctors of various specialisations. After a long-lasting period of neurological, laryngological, orthopaedic and maxillofacial diagnostics, the patients turn to dentists, where a diagnosis is provided, and the attempts of treatment are undertaken to decrease the patients' discomfort [261–263]. Unfortunately, the effects of the treatment do not last long or they rely on using orthopaedic repositioning or relaxing splints. Splints are becoming part and parcel of the therapy that often takes many years [264–269]. The effect of malocclusion on the TMJ has been comprehensively described. However, there remain about 30% of patients with proper indications for the canine teeth and skeleton according to Angle's classification as well as normal occlusion height where problems with the joint are manifested as pain, discomfort, clicking or cracking [270, 271].

It is more often the case that a dentist seeks a physiotherapist's help to complement dental treatment. Integrated dental and physiotherapeutic care may be very effective in the diagnosing process and rehabilitation of patient with the aforementioned disorders and provide long-lasting therapeutic effects. It is possible thanks to the elimination of diagnostic errors as well as influencing all anatomical structures that may be responsible for the problems reported by the patient [272].

Substance of the issue – Evidence for the considerations above

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Temporomandibular joint disorders (TMD) are not a single diagnosis. They are more a set of diseases that encompass various conditions, and, consequently, various clinical symptoms. TMD affect 15% of adults, with the prevalence peak between 20 and 40 years of age. The problem is twice as common in women. It is also worth mentioning that smoking increases the risk of the disorder in women under 30 years of age [273, 274]. Malfunctioning of the TMJ can be divided into intra- and extra-articular. Adaptive mechanisms are responsible for the fact that most dysfunctions in a joint develop imperceptibly. Such imperceptible development was described as a painless dysfunction of the masticatory organ. Only 5% of patients seeking medical attention complain about specific symptoms. In the light of this fact, it is possible to confirm the development of the symptomatic syndrome of the masticatory organ that can be referred to as a pain masticatory dysfunction, myofascial pain or maxillofacial pain [275, 276]. With regard to the source of the pain, there is a muscular and articular form of the syndrome. Myalgia is constant, dull, stabbing, and difficult to localise. Arthralgia is also dull, diffused, and increases with a change of body position.

The aetiology of TMD is multifarious and not fully understood. It is known that occlusion conditions, injuries of the mandible, parafunctions, dysfunctions, and caries influence the development of the disorders in the joint concerned [277]. Most recent studies point to muscular tension as one of the more important causes of pathology development in a joint [278]. Long-term muscle overload leads to an improper functioning pattern that is transferred onto the joint, disordering adaptive mechanisms. The pattern of anterior or posterior posture also determines the type of occlusion.

Some cranio-mandibular dysfunctions also cause abnormalities: lateral flexion in the atlanto-occipital joint, secondary compensation in the atlantoaxial joint or restrictions within the hyoid bone. It was shown that this abnormality may cause scoliosis [279], deepening of spinal curvatures and pelvic asymmetry. The image of the stomatognathic system shows the presence of cross-bite, open bite or posterior bite (Fig. 1A and B and Fig. 2).

Fig. 1. A and B. An intraoral photo of a patient who was orthodontically treated due to a posterior bite
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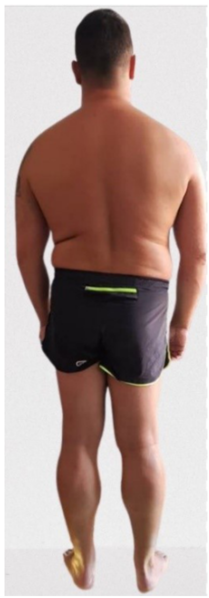

Fig. 2. A patient with shortening of the right limb (43 mm) and lowering of the right iliac ala. In the sagittal plane, the shoulders in protraction, hyperextension of the right knee. In the transverse plane, rotation of the pelvis to the right

Retrusion of the mandible is another example of cranio-mandibular dysfunction causing a shift of the projection of the centre of pressure to the front. It will correlate with increased lordosis of the cervical and lumbar spine, and anterior pelvic tilt (Fig. 3, 4, 5, 6).

Fig. 3. An intraoral photo of a patient with total supraocclusion.

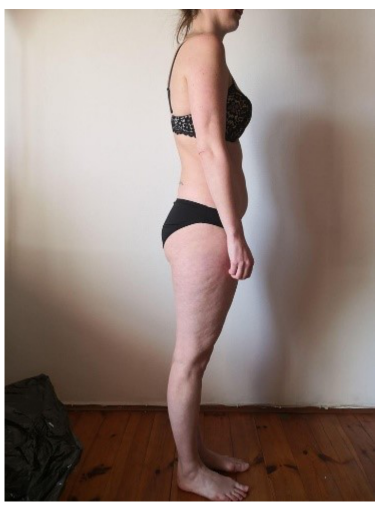

Fig. 4. In the sagittal plane, increased cervical lordosis, protraction of the shoulders, increased lumbar lordosis – anterior pelvic tilt – hyperextension of the knees, hallux-valgus in both feet

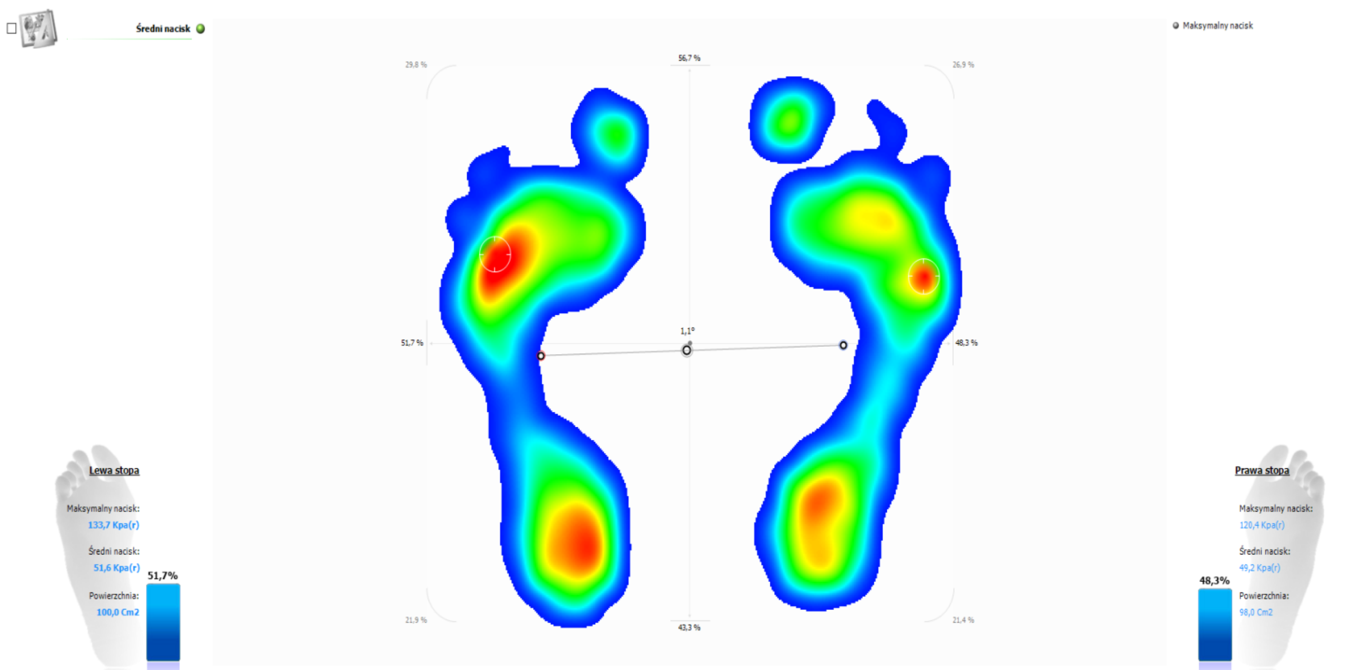

Fig. 5. The result of projection of the centre of pressure onto the ground and foot barycenter, with a shift of the centre of pressure to the front

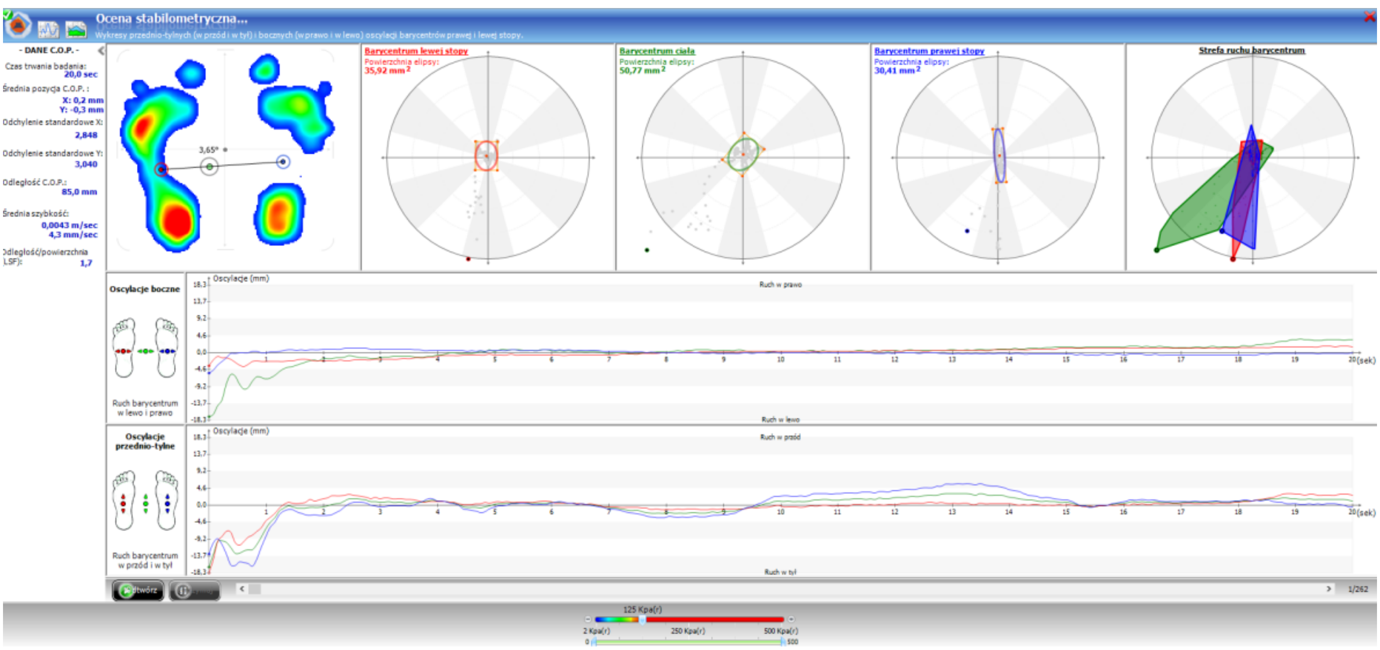

Fig. 6. The result of the body balance test, with a clear predominance of posterior oscillations as a result of balancing the anterior tilt of the silhouette

On the other hand, shifting the projection of the centre of pressure to the back will cause flattening of cervical and lumbar lordosis, and protrusion of the mandible (Fig. 7, 8 A and B) [280, 281].

While diagnosing TMD, it is important to determine whether this is an ascending or descending dysfunction. The reason for this lies in the fact that the symptoms will manifest themselves in the TMJ, whereas the cause of the dysfunction can be localised apart from the joint. Barr, Zink, Meesserman, Fukuda tests are good tools to assess ascending or descending dysfunctions [282]. In the case of the TMD, it is important to determine a posture pattern, as described by Hall, Wernham and Litteljohn [283]. Anterior and posterior posture patterns can be distinguished causing not only malocclusions but also dysfunctions in the following systems: osteomuscular, respiratory and circulatory, and visceral (Tab. 1).

Fig. 7. An intraoral photo of a patient with inferior prognathism

Fig. 8 A and B. In the sagittal plane, flattened cervical and lumbar lordosis, posterior pelvic tilt. In the transverse plane, external rotation of both lower limbs, the feet are hollowed, adduction of the left forefoot. In the frontal plane, asymmetry of the pectoral muscles resulting from protraction of the left shoulder and, consequently, internal rotation of the upper limb

Table 1. Posture patterns according to Hall

Area	Anterior pattern according to Hall	Aosterior pattern according to Hall
the osteomuscular system	• a deepened cervical lordosis • increased tension in the cervicothoracic transition • increased tension of back muscles and spinal ligaments • ankylosis and increased tension at Th_{11} and Th_{12} • increased tension of the lumbosacral transition	• occipital bone in extension and compression • increased tension in the cervicothoracic transition • a deepened thoracic kyphosis and decreased tension of lower thoracic segment • compression of the sternal articulations • an enlarged lumbar lordosis • an overload of the sacroiliac joint
the circulatory and respiratory system	• tension of the diaphragm, often during inspiration • weakened and overly stretched abdominal muscles	• tension of the diaphragm, often during expiration • upset balance between the abdominal cavity and chest pressure • an increase in the tension of the abdominal cavity walls
the visceral system	• ptosis of internal organs • loosening of the parietal peritoneum • proneness to hernias and irritation of the true pelvis area	• increased pressure on the abdominal cavity and pelvis organs • proneness to disorders of the circulatory system • proneness to problems with the respiratory system • proneness to constipations

Many clinical studies have been carried out that, based mainly on an interdependence of skull and mandibular dysfunctions on the cervicothoracic and lumbar spine, describe the relationship between TMD and human posture (Fig. 9 A, B, C, and Fig. 10) [247, 284].

Figures 9 A, B, C. An intraoral photo of a patient with right-sided partial lateral cross-bite and crowded mandibular incisors

Figure 10. A patient with multifaceted posture disorders visible in the sagittal plane (protraction of the head and shoulders, increased cervical and lumbar lordosis, thoracic kyphosis – with simultaneous anterior pelvic tilt and pelvic protrusion (in the pelvis-head line); hyperextension of the knees, external rotation of the limbs with broad-based balance spacing of the feet)

Figure 11. A and B. An intraoral photo of a patient with distoclusion and protrusion of the maxillary incisors

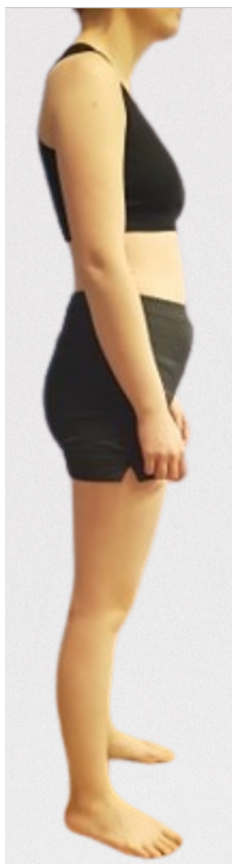

Figure 12. A patient with protraction of the head and shoulders, increased cervical and lumbar lordosis, thoracic kyphosis – with simultaneous anterior pelvic tilt and pelvic protrusion (in the pelvis-head line); hyperextension of the knees, external rotation of the limbs with broad-based balance spacing of the feet

Figure 13. A and B. An intraoral photo of a patient with right-sided partial lateral cross-bite

Figure 14. A and B. In the sagittal plane: protraction of the head, increased cervical and lumbar lordosis, asymmetrical planovalgus feet. In the frontal plane, in the lateral right-sided position, asymmetry of the shoulders, increased internal rotation of the left limb, significant left planovalgus foot, both flat feet

It should also be mentioned that a specific posture pattern of a patient with TMD does not only affect the position of the cervical spine, but also significantly influences the possibility of the trapezius and levator scapulae muscle hyperactivity development and deepens lumbar lordosis. This is directly linked with a pathological and excessive pelvis anteversion and bending of the iliac joints, contributing in this way to the hyperextension of the knees (Fig. 15, 16) [288, 289].

Fig. 15. A patient with mixed dentition, distoclusion and protrusion of the maxillary incisors

Fig. 16. In the frontal plane, the torso flexed to the right, valgus knees. In the transverse plane: increased rotation of the left upper limb, asymmetrical lower limb rotation (increased internal rotation of the right lower limb), adduction of the right foot

Discussion

Studies by Maeda were carried out to reveal a correlation between the deviations of the length of a lower limb and the patient's occlusion. To investigate this correlation a range of tests were done in which patients were alternately raising their heels while motions in their TMJ were being observed. The results confirmed the correlation between the raising of the right heel and shifting occlusion forces to the right [290, 291]. On the other hand, studies by Bonato were focused on a relationship between the pain in the TMJ and pain in other distant joints: hip, knee, ankle, or wrist. Bonato concluded that the risk of pain transferred into another joint was 5.5 times higher in patients with TMD. The complaints of the patients examined mainly concerned knee joints [292].

With tensegrity theory in mind, Souza et al. assessed the pressure exerted on a foot and its spreading in patients with a diagnosed TMD. The study demonstrated a statistically significant correlation between the spreading of the pressure exerted on the planta and a pathology within the TMJ [293]. The study initiated a discussion on the interdependence between the foot and the stomatognathic system; an interdependence whose existence has been denied by Saito [294]. Valentino is of the opposite opinion and describes planta stimulation that increases tension in the masseter and temporalis muscles [295]. According to Gonzalez and Manns, a head in protraction (when the head is moved forward) is characterised by hyperextension in the upper part of the cervical spine C_1–C_3 as well as increased curvature in its lower segment C_4–C_7, which leads to hyperlordosis [296]. Correlations between the position of the head and cervical spine and temporomandibular joint dysfunctions were investigated in many studies. It should be stated here that opinions on the issue are divided. Many researchers have observed the dependence [247, 285–291]. Others have not found any significant correlation [296-300]. The studies into the conditions of the joint under investigation should be conducted in accordance with the Research Diagnostic Criteria for TMD's (RDC/TMD) [275]. The head's position is assessed on the basis of cephalometric or photographic measurements of the C_0-C_1 distance as well as a craniocervical angle (CVA). The craniocervical angle serves as a tool for the measurement of the angle between a line marked horizontally through the spinous process of the seventh cervical vertebra (C_7) and a line in the middle of the antilobium [301]. Visscher et al. did not note any important changes in the head's position of the patients with the TMD in comparison to the control group [296].

In the studies by Shweta Channavir Saddu, an additional study group of the TMD patients was created. The group included patients with muscular and articular dysfunctions with an articular disc dislocation. No relationship was confirmed between the head posture and the TMD. Interestingly however, a cervical lordosis was observed in patients with a temporomandibular joint dysfunction of muscular origin [302]. Sonnensen has drawn a similar conclusion. In studies conducted on a group of children, he proved that the head in protraction with concomitant reduced motility and cracking in the joint [299]. Pedroni et al. also confirmed the relationship between joint disorders and the position of the head and the cervical segment [275]. 68% of the subjects in the group of students with TMD had an extension in the cervical segment as well as the arms positioned to the front. A dysfunction of the cervical segment usually manifests itself with pain as well as abnormal motility in the musculoskeletal structure of the cervical spine. Concomitance of a cervical spine dysfunction and TMD has been confirmed by the findings of clinical studies [250, 251, 301]. The researchers coined the term 'the triad of dysfunction', which suggests a relationship between myofascial pain, internal pathologies in the TMJ as well as a musculoskeletal dysfunction of the cervical segment of the spine [259, 285]. Examining this relationship, Bragatto confirmed a higher percentage of the incidence of TMD among women working in the sitting position (at a computer) who reported chronic pain and neck instability [251]. De Wijer points to the necessity of more comprehensive diagnostics for patients with chronic symptoms from the head and neck area [303]. It seems reasonable not to treat TMD as a local, separated problem, but to also extend diagnostics for the cervical segment of the spine and the shoulder girdle. Studies by Wijer indicate that symptoms from the TMJ and a dysfunctional cervical segment are concomitant. An orthopaedic test for the cervical segment is applied to recognize the source of the pain [303, 304]. In her studies, Weber did not find a relationship between the craniocervical position and TMD. The researcher emphasized the fact that the concomitance of the cervical spine dysfunctions and TMD is related with the common nervous track originating from the trigeminal nerve. Remarkably, in this study, patients with a concomitant condition of a joint experienced pain under palpation in the neck muscles and along with its movements [250, 285]. A study conducted at the Medical University in Zabrze, Poland, is also worth mentioning. Patients experiencing pain and with reduced motility of the cervical segment were the subjects of this study [305]. The subjects underwent the therapy with the relaxing SVED splint. A significant pain reduction in the TMJ, but also in the cervical segment, whose motility increased, was achieved after 3 months of treatment. A motility improvement as regards the cervical segment of the spine substantiates the tensegrity theory in the context of the relationship between the TMJ and the osteo-myo-fascial track of the lower segments of the spine.

A patient's posture pattern, wherein a temporomandibular dysfunction occurred, means more than only the aforementioned head protraction and cervical hyperlordosis, but also hyperactivity of the upper part of the trapezium and the levator scapulae muscle, rounded neck, deepened lumbar lordosis, compensatory bending of the iliac joints, pelvis anteversion and hyperextension of the knee joints. A few theories explain such a distant range of interdependent disorders. One of them was put forward by H. Diers. The researcher divided disorders into ascending (originating in the lower parts of the body) and descending ones (from the TMJ) wherein the tension is transferred by the proprioceptive system.

The myofascial theory, presented by Myers, points to the existence of fascial bands along which information is being transferred. Types of information include pathologies that initially ignite one dysfunction and then abnormalities in even distant organs [306]. Myers divides fascial bands into the posterior surface band that stretches from the planta to the top of the head; the anterior surface band running from the instep to the lateral part of the skull; and the anterior deep band. The bands' role is to maintain the body posture and the centre of gravity. They act as transmitters for stimuli that confirm the existence of the tensegrity model. Pressure or increased tension in one location results in heightened pressure in other tissues, which proves the integrity and interrelation of the myofascial chains with surrounding tissues. Manheim defined myofascial relaxation as facilitation of the mechanical, neuronal and psychophysical adaptive potential that cooperates and manifests itself through the myofascial system [307, 308]. Many researchers proved the effectiveness of myofascial relaxation in the reduction of pain, including the pain of the TMJ, as well as in restoring a good body posture. Both factors increase the level of the patient's quality of life [309–315]. Many research papers were published in which it was evidenced that postural changes may cause or may just predispose a person to the TMD [275, 316–318]. However, it should be mentioned that theses contradicting the aforementioned stance are also present in the literature [319]. Some studies point to the improvement in the TMJ following physiotherapy or postural re-education [318, 320]. In his studies, Saito confirmed the existence of postural changes in the form of pelvis rotation towards the back (pro-posterial), lumbar hyperlordosis, extension in the thoracic segment and pathological leaning of the head to the right, whilst the mandible to the left, with the mouth open. All these symptoms were present in patients with the TMD (with the previous articular disc dislocation) [321]. Wright evaluated a relative risk of the occurrence of the TMD in patients with an asymmetry of the shoulders of about 5.9% [318]. According to Park, performing appropriate exercises could restore normal movement extent in the TMJ in a significant number of patients suffering from mild scoliosis (10 degrees) [322].

Himiko Ikemitsu et al. investigated a correlation between the direction of the movement of the mandible and scoliosis in patients withTMD. Their study indicated only a relationship between TMD and scoliosis. No correlation was found between the direction of the lateral movement of the mandible [323]. Pain in the lower segment of the spine is common. The system of pelvic joints significantly affects the development of the human body's posture. Their lateral relocation results in a lateral curvature of the spine, when the curvature of the pelvis to the back increases lumbar lordosis, whereas to the front it increases thoracic kyphosis. Numerous studies have been conducted to investigate whether such distant structures as the pelvis, namely its disorders, and the TMJ can affect each other. The findings confirm their interdependence [324, 325]. The work by Zonnenberg et al. is a valuable example of such a study. The main objective of their study was to indicate differences in the setting of the pelvis and the neck in a group of patients with a dysfunction of the TMJ in comparison to the control group (patient without pathologies in the TMJ) [317]. A setting of the aforementioned bony structures was evaluated by marking topographic lines between the acromions, and the anterior and posterior pelvis spurs. Zonnenberg showed that patients with TMD have, in comparison to the control group, a statistically disturbed system of the topographical lines. Body weight should be spread evenly over the largest possible area [317]. Carrying body weight relies on the feet. They are also the location where muscle chains end, whose role, according to the tensegrity theory is to transfer the load to the upper anatomical structures, which causes anomalies in the correct body posture. Tension of the fascia does not depend on muscle tension. This is due to the existence of autonomous nervous fibres that regulate initial fascial tension with the use of the contractibility of the non-striated muscles [326-328].

Summary

The human body may be termed as a tensegrity structure. This means that a change in the tension of the fascia, tendons and muscles, the structures distant from the head, leads to the TMD, using the transferring mechanism [329]. A proper body posture is characterised when particular segments are placed harmoniously against one another ensuring the flexibility of movements and stability of the support, with the lowest possible energy cost. Every change in the system, of one segment against another, causes changes in the other segments [330]. On the basis of the findings in many publications it was proved that the change in the statics and the function of joints distant to the TMJ is responsible for various dysfunctions of the aforementioned structure. The contrary dependence has also been confirmed. Therapy of particular limb joints or the spine led to a considerable reduction of problems in the TMJ.

Conclusions

Studies on tensegrity provide a lot of information, which changes the way of diagnosing and the treatment of the patient with dysfunctions. Specific structural elements should not be treated and analysed separately, but a holistic approach should be applied. It is worth realizing that disorders of the masticatory system should be treated by an interdisciplinary team, and not by one professional. The interdisciplinary team should include a dentist, physiotherapist, orthopaedist, logopedist, laryngologist and psychologist. Only through a joint and compatible effort of such a team, can the relative benefits be achieved in the context of the improvement in the functioning of the TMJ, as well as the organism as a whole. It should be mentioned that further studies are advisable in order to complement the currently available knowledge on tensegrity.

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