Comparison of Psychologic and Physiologic Functioning Between Patients With Masticatory Muscle Pain and Matched Controls

This study explored the physiologic and psychologic distinctions between masticatory muscle pain patients and age and sex-matched normal controls. Subjects completed several standardized psychologic tests. They then underwent a laboratory stress profile evaluation to obtain physiologic measures (EMG, heart rate, systolic and diastolic blood pressure) under conditions of rest, mental stress, and relaxation. The pain patients reported greater anxiety, especially cognitive symptoms, and feelings of muscle tension than did the controls. Under stress, pain patients had higher heart rates and systolic blood pressure than the controls. Electromyogram activity in the masseter regions was not significantly different between the pain and control group. The results are discussed in terms of the likely mechanisms that might account for the observed differences between masticatory pain patients and normal subjects.

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Forty years ago, Moulton[1] listed four potential mechanisms by which emotional and physical habits might influence muscle dysfunction in the facial region. These mechanisms included behavioral patterns related to dental care and food use, hysterical conversion, destructive oral habits that cause structural damage or unremitting pain, and autonomic nervous system disregulation caused by anxiety. Moulton noted the third category, destructive oral habits, as the primary cause of most of the temporomandibular disorders (TMD) among the patients she observed in clinical practice. Much of the dental literature for the past 40 years has followed a similar direction and focused on the role of destructive oral habits in temporomandibular pain and dysfunction. Consequently, the dental community has placed significant emphasis on the role of excessive muscle activity in the development and maintenance of TMD.

Recently, there has been controversy regarding the role of excessive muscle activity in the etiology of TMD.[2] Numerous studies[3–7] have purported to document the presence of postural hyperactivity and elevated resting electromyogram (EMG) activity of persons with TMD and these are often described as myofascial pain dysfunction syndromes. The majority of these studies, however, contain methodologic flaws involving subject selection criteria, age and sex matching between pain patients and control subjects, variations in body position during evaluation, and discrepanices caused by movement during the evaluations. One well-controlled study[8] that compared facial pain patients and matched controls reported that EMG activity in the right masseter region is greater only when stressors are applied. However, another well-controlled study[9] did not find elevated masseter activity during rest or stressful periods. Thus, there is considerable diversity of opinion regarding the central role of muscle overactivation in TMD.

Lund[2] noted that if postural hyperactivity of the masseter muscles were a causal factor in TMD, then greater activity would be observed in the orofacial muscles on the afflicted side of the face than on the contralateral side. This has not been clearly established. For example, Dolan and Keefe[6] found that in patients reporting pain on the right side, the greatest EMG activity was observed on the left masseter. For subjects experiencing left-sided muscle pain, no differences in EMG activity were noted between the left and right masseter regions. In short, the hypothesis of elevated muscle activity for TMD patients has not received consistent support in the literature.

One principle that has been overlooked in recent discussions of TMD etiology is the concept of autonomic response stereotypy.[10] Response stereotypy refers to the likelihood that an individual reacts to stressors with a unique pattern of autonomic activation that may include musculoskeletal, cardiovascular, and respiratory changes. Such a unique reactive pattern of autonomic activation may characterize TMD patients and be responsible for the symptoms observed in the clinic and laboratory.[7] With the primary emphasis currently on evaluating EMG activity, however, we may be missing the opportunity to identify reactive patterns involving multiple physiologic systems. In several reports[4-7] investigators comparing TMD patients to normal subjects found no changes in heart rate or electrodermal activity in response to laboratory challenge even though EMG differences were observed. Such evidence seems compelling at first glance and may have focused our attention away from disregulated patterns of autonomic activity and toward another symptom, namely EMG activity. Unfortunately, increased EMG activity may or may not be present, because an individual may respond to stressors with a unique pattern of autonomic activation that may or may not include identifiable skeletal muscle activity.

The present study was conducted as a part of a larger research project exploring the evaluation and treatment of TMD. This portion of the project addressed the psychologic and physiologic parameters that might distinguish TMD patients from age- and sex-matched control subjects. Exploration of the psychologic parameters differentiating pain patients from appropriate control subjects has generally supported the notion that such patients experience more anxiety than normal subjects.[11-13] Moreover, research has suggested these patients also feel less in control of their own outcomes than normal subjects.[12] Thus, an attempt was made in this study to replicate these previous psychologic findings as well as evaluate differences in physiologic activity. The central hypothesis was that physiologic indices of autonomic nervous activity (heart rate, blood pressure, peripheral skin temperature) may differentiate pain patients from matched controls even though EMG activity may not. Special care was taken to control for body position during the evaluations because body position is known to influence the activity of the masseter regions.[14] Furthermore, an elaborate screening procedure was used to identify a homogenous patient sample characterized as experiencing masticatory muscle pain[15] without temporomandibular joint (TMJ) pathology.

Materials and Methods

Subjects

The study sample included 34 patients who were seen at the Orofacial Pain Center at the University of Kentucky College of Dentistry and 18 normal subjects who were recruited from the university community. The patient sample, which comprised 32 women and 2 men with an average age of 34.1 years, participated in another, previously published, research project concerning the efficacy of relaxation procedures.[16] In that study the patients were randomly assigned to one of two treatment groups and examined by a dentist who had extensive experience with TMD. Each patient accepted for the study was diagnosed as having primarily masticatory muscle pain with no clinical evidence of joint pathology or dysfunction. There was notable muscle tenderness to palpation, and any decreased range of mandibular movement was secondary to muscle dysfunction and not TMJ involvement as determined by physical and radiographic examination. The Orofacial Pain Center is primarily a secondary referral center; thus, by the time patients came to the center for treatment, they had been experiencing prolonged discomfort, ranging from 1 month to several years. In addition, subjects did not have previous experience with relaxation training.

The control sample, which included 17 women and 1 man, was derived by matching subjects by age and sex to the two patient samples, with the ages matching to within a 1- to 3-year range so that each of the three groups had an equivalent age distribution. Normal controls were screened by a licensed physical therapist with several years' experience treating TMD. During the screening they described themselves as in good general health with no reported TMJ dysfunction or pain. In addition, the physical therapist completed a brief physical examination of the head and neck region to verify normal functioning.

Experimental Setting and Experimenters

The study was conducted with subjects seated in a dental chair in a quiet room with low-level lighting. The chair was reclined so that the person was resting in a position with the feet and head in horizontal alignment. Two trained experimenters, one male and one female, administered the evaluation protocol to the patient subjects. Each of these experimenters saw an equal number of pain subjects in each condition; the normal controls were seen by one male therapist because of scheduling constraints.

Procedure

Subjects completed a battery of psychologic tests while the experimenter attached the physiologic recording leads according to standard laboratory guidelines.[17] Placement of the EMG sensors was standardized using major anatomic landmarks that enabled positioning at the midpoint of the muscle belly (motor point) with the active electrodes placed parallel to the muscle fibers. For the masseter, this involved placing the electrodes at the midpoint of a line from the lateral corner of the eye to the angle of the mandible.

Physiologic measures were recorded using a computerized physiograph (J+J I-330, J+J Inc, Poulsbo, WA). Electromyogram activity in the left and right masseter and trapezius regions was monitored using silver/silver chloride miniature surface electrodes according to the technique of Cram[18]; use of this technique in our laboratory has resulted in skin resistances well within the requirements of the EMG preamplifiers of the J+J I-330 system. The skin temperature of the palmar surface of the distal phalanx of the left index finger was measured with a thermister probe sensitive to 1/160 of a degree/micromho. Blood pressure and heart rate were measured with an automated blood pressure system (Paramed 9200, Paramed Technology Inc, Mountain View, CA) with the cuff placed on the right arm.

After the questionnaires were completed and recording sensors were attached, subjects reclined quietly for a 5-minute baseline recording. This was followed by three 1-minute trials of mental arithmetic (serial subtraction of 13s from a four-digit number) with 1-minute rests between trials. (This task was chosen because of its frequent use as a laboratory stressor in TMD pain research.[19]) The subjects were guided into a relaxed position, using the procedures outlined by Poppen.[20] Additional muscle-relaxation activities besides those of Poppen were used with one of the experimental groups; therefore, procedures for the matched control group following postural relaxation were similar to only one of the two patient groups. After the relaxation period, physiologic recordings were obtained for a 15-minute postbaseline period. Self-ratings of emotion were collected during the baseline, mental arthmetic, and postbaseline periods; self-ratings of muscle tension were collected during the baseline and postbaseline periods.

Dependent Measures

Physiologic Recording. Electromyogram data were integrated over 1-second epochs during each of the experimental phases. An average score for each phase of study was then computed; during the postbaseline phase, data for the first 5-minute period were used in the statistical analyses because preliminary analyses indicated no differences between the three 5-minute phases in the postbaseline period. Skin temperature was also measured and recorded over 1-second intervals; averages for each period of the study were used in the analyses. Heart rate and blood pressure were taken at the end of each phase of the experiment, after EMG and skin temperature recordings had been made, with the exception of during the mental arithmetic task, when they were obtained during the first 1-minute trial.

Psychologic Instruments. Level of anxiety was measured with the State-Trait Anxiety Inventory.[21] In addition, characteristic anxiety-response patterns were evaluated with the Cognitive-Somatic Anxiety Questionnaire.[22] Beliefs regarding responsibility for health were measured with the Health Locus of Control Scale.[23] Self-reports of muscle tension were made using the Tension Mannequin.[24-25] Self-ratings of emotion were obtained using the Emotion Assessment Scale,[26] and beliefs regarding the ability to relax were measured using a 10-cm visual analog scale with which persons were asked to rate their beliefs about their current abilities to relax.[27]

Table 1 Summary of Physiologic Data of the Two Groups of Muscle-Pain Patients (MMP-1, MMP-2) and the Control Group

	MMP-1 (n = 17) Mean	(SD)	MMP-2 (n = 17) Mean	(SD)	Controls (n = 18) Mean	(SD)
EMG left masseter						
Baseline	2.44	(1.17)	4.63	(6.58)	2.73	(1.53)
Mental arithmetic	4.58	(1.66)	6.30	(3.66)	5.73	(2.91)
Postbaseline	2.24	(1.04)	—		2.20	(1.77)
EMG right masseter						
Baseline	2.96	(1.83)	3.28	(2.29)	2.37	(1.19)
Mental arithmetic	4.90	(2.18)	5.19	(2.16)	5.80	(3.10)
Postbaseline	2.59	(2.19)	—		2.06	(1.08)
EMG left trapezius						
Baseline	2.34	(4.36)	1.97	(2.33)	1.43	(0.86)
Mental arithmetic	2.77	(4.97)	6.06	(11.41)	1.70	(1.19)
Postbaseline	2.94	(4.71)	—		1.66	(1.84)
EMG right trapezius						
Baseline	3.07	(5.35)	1.49	(0.83)	1.22	(0.53
Mental arithmetic	3.34	(5.21)	2.02	(1.99)	1.29	(0.55)
Postbaseline	8.38	(19.31)	—		1.23	(0.71)
Heart rate						
Baseline	71.6	(14.8)	68.1	(8.0)	69.2	(12.9)
Mental arithmetic	85.6	(12.9)	81.9	(15.0)	71.6	(16.3)*
Postbaseline	70.3	(14.9)	—		66.6	(12.4)
Systolic blood pressure						
Baseline	118.3	(11.6)	120.4	(17.1)	114.2	(12.4)
Mental arithmetic	129.5	(11.2)	129.1	(12.9)	119.8	(15.6)*
Post baseline	122.6	(6.9)	—		113.6	(11.2)
Diastolic blood pressure						
Baseline	62.4	(17.1)	66.2	(12.1)	65.2	(8.8)
Mental arithmetic	73.4	(8.8)	74.6	(8.8)	70.1	(12.8)
Postbaseline	68.6	(9.9)	—		68.7	(10.2)
Skin temperature						
Baseline	81.96	(7.95)	83.06	(6.76)	86.7	(7.2)
Mental arithmetic	80.24	(7.56)	82.62	(6.15)	85.6	(7.5)**
Postbaseline	80.06	(7.64)	—		82.9	(8.9)

*$P < .05$
**$P < .1$

Results

The data from the psychometric evaluations and initial physiologic baseline were compared across the three experimental groups using analysis of variance (ANOVA); to control for the possibility that initial baseline values might influence subsequent responding, an analysis of covariance (ANCOVA) was used for the dependent measures obtained during the mental arithmetic task. Data from the postbaseline were evaluated with ANCOVA procedures using the patient group that experienced postural relaxation only and the matched control group (who also experienced postural relaxation only) as the comparison groups. All analyses were conducted using the general linear model of SYSTAT.[28] Significant findings were followed with post-hoc contrasts using the Bonferroni procedure to control for family-wise error rate. The degrees of freedom are not constant across all analyses because of missing data.

The two groups of masticatory muscle-pain patients (MMP) reported significantly more trait-anxiety (Xs = 41.65, 47.71) as measured by the State-Trait Anxiety Inventory than the matched controls (MC; X = 33.29, $F[2,48] = 8.81$, $P <$

.001). These results suggest that pain patients experience more enduring anxiety than do normal controls. Similar results were found for state-anxiety (anxiety at the moment of evaluation) where MMPs reported more state-anxiety (Xs = 39.65, 42.06) than did MCs (X = 32.61, $F[2,48] = 5.46$, $P < .01$). The Cognitive-Somatic Anxiety Inventory data revealed no differences among groups on the somatic symptoms subscale ($F[2,49] = .76$), but there was a significant difference among groups on the cognitive symptoms subscale ($F[2,49] = 4.07$, $P < .02$; MMP Xs = 17.18, 21.77 vs MC X = 15.06). These findings indicated that pain patients experience significantly more cognitively oriented symptoms of anxiety than do normal controls, but there were no differences on reports of somatically oriented symptoms of anxiety.

Muscle pain patients rated themselves as less confident of their ability to relax than did MCs, ($F[2,49] = 5.03$, $P < .01$; MMPs X = 34.41, 40.29 vs MC X = 58.44). Muscle pain patients also rated themselves as experiencing more muscle tension at the baseline period (X = 642/692) than did controls (X = 305, $F[2,49] = 8.45$, $P < .001$). We failed to find significant differences among groups on health locus of control beliefs or other measures of ongoing emotional states taken at the initial baseline.

Emotional response during the stress period was evaluated using three-way ANCOVAs, with the covariate being the initial baseline score for the emotion category. This analysis strategy was employed in accordance with the Law of Initial Values[27] to control for baseline differences in emotion that may influence responses during the stress period. These analyses revealed significant differences among groups for self-ratings of happiness ($F[2,48] = 3.11$, $P < .05$, MMP X = 9.1, 10.5 vs MC X = 17.2). There was a similar, but not significant, difference among groups for self-ratings of anger during the arithmetic task ($F[2,48] = 2.76$, $P < .07$, MMP X = 31.2, 35.5 vs MC X = 15.7).

During the baseline evaluation there were no significant differences among the groups for resting EMG activity at each of the four muscle sites. There also were no significant differences among the groups for skin temperature, heart rate, or blood pressure. In accordance with standard procedures for analyzing physiologic data reflecting change across time,[17] three-way ANCOVAs were computed using the respective baseline score as the covariate for each of the physiologic variables during the stress phase. A pattern of results suggesting sympathetic activation via the cardiovascular system emerged from these analyses. There was a significant difference in heart rate response among the groups ($F[2,47] = 6.52$, $P < .003$), as well as in systolic blood pressure ($F[2,49] = 3.10$, $P < .05$). In addition, there was a marginally significant difference in skin temperature responses ($F[2,49] = 3.06$, $P < .06$). The physiologic results are presented in Table 1.

Because one of the MMP groups and the matched controls followed identical experimental protocols, it was possible to make comparisons on these subjects' postbaseline scores. These comparisons were done using a two-way ANCOVA procedure in which the initial baseline score for the dependent measure served as the covariate for the analyses of that variable. There were no differences between the groups for EMGs, heart rate, blood pressure, skin temperature, self-reports of muscle tension, or emotion ratings between the patient group and the control group with respect to recovery from the stressor.

Discussion

The results of this study suggest that current ideas regarding the etiology and management of masticatory muscle disorders might need to be reevaluated. For years, the accepted primary cause of masticatory muscle pain has been muscle hyperactivity. Thus, the dental profession has attempted to assess the relationship between this muscle hyperactivity and dental factors such as malocclusion. Numerous diagnostic and therapeutic approaches have been developed based on increased EMG activity. However, our results suggest that the resting EMG activity of a group of masticatory muscle–pain patients is no different than that of a control sample when subjects are placed in a supine position. Moreover, when patients and controls are physiologically and psychologically stressed with a standardized stressor, EMG activity increases in both groups, and there is no statistically significant difference in the increases. It would be difficult, therefore, to use EMG activity as a diagnostic tool to differentiate pain patients from controls using this clinical protocol. These results should be qualified, however, because EMG activity was evaluated over specific time periods in the protocol and only a single laboratory stressor was used.

Another issue potentially affecting the interpretation of our results is whether the supine body position may have influenced the findings. Several of the more recent studies evaluating EMG activity[3–5] used a sitting position where patients were encouraged not to move their heads. It is not clear in these studies, however, to what extent the head was actually supported by the chairs that were used. Dolan and Keefe[6] have shown that there is no difference in EMG activity of the masseter regions between reclining and sitting positions when muscle-pain patients are evaluated. While proper patient positioning for muscle evaluation is open to debate, it is apparent that future research should address the issue of muscle activity and body positions more closely. We intentionally used the supine position in this study to control extraneous movements and to ensure standardization of body positions.

Given the similarity in EMG activity during rest, stress, and recovery between the patient and nonpatient samples, it would be difficult to account for the muscle pain in the patient group solely on the basis of EMG activity differences because we did not observe such, even under the stressful conditions of the laboratory. Perhaps it is time for the dental profession to redirect its attention to other differences that exist between muscle-pain patients and matched controls. The marked variance in levels of self-rated anxiety, as well as the differences in heart rate, systolic blood pressure, and skin temperature during the stressor are noteworthy in this regard. These latter physiologic variables are measurements generally characteristic of sympathetic nervous system activity. Perhaps the muscular pain is not due to muscle hyperactivity per se, but instead is a reflection of vascular, neuronal, structural, or chemical changes in the intramuscular tissues as a result of or in association with generalized sympathetic overactivity.

Masticatory muscle–pain patients may be a group of persons who typically overrespond to life stressors with excessive sympathetic activation. Excessive sympathetic responsivity may then contribute to the intensification of pain experience in this group of individuals. If there is the possibility that hyperactivity of the sympathetic nervous system is a major contributor to the presenting complaints, perhaps treatment should include altering the sympathetic nervous system response instead of altering muscle function alone. While our data do not preclude the possibility that muscle hyperactivity may contribute to masticatory muscle pain, it appears that other physiologic factors may also be playing a significant role. This issue, however, awaits further experimental evaluation.

One aspect that laboratory studies do not address involves the activity of the muscles in the natural environment. It is well documented that bruxers have elevated muscle activity both at rest and during function in the natural environment[2] and that reductions in muscle activity among these persons often result in fewer reports of pain. However, to our knowledge, similar evaluation studies have not been done with masticatory muscle–pain patients. It would be useful to monitor the masseter EMG activity of these patients, as well as matched controls, to determine whether pain patients have elevated EMG activity during their daily routines. Such an approach may provide more definitive information regarding the link between environmental stressors and muscle activity, similar to that which has been obtained from bruxers.[29] It may also help patients identify potential problem periods for muscle overactivity during their normal routines.

The data suggesting a pattern of sympathetic overresponding to laboratory stressors among masticatory muscle–pain patients begs the question of what then is responsible for the excessive sympathetic activity. In other areas of inquiry, such as cardiovascular reactivity,[30] it has been noted that both hereditary and environmental factors mediate hyperresponsivity. Because etiology of excessive sympathetic responsivity is likely to be multifactorial, the clinician should gather a detailed psychosocial history to determine whether there are significant biologic or interpersonal factors likely to influence the level of physiologic arousal. For example, consider the possibilities that sexual abuse might play in contributing to excessive sympathetic activation. Recent estimates suggest that sexually abused persons comprise 40% to 60% of patients with facial pains.[31–32] A history of abuse might predispose the patient to respond to environmental challenge with excessive sympathetic activation and may also contribute to the frequent reports of high anxiety from masticatory muscle–pain patients. Further research is needed to explore the potential factors contributing to this excessive pattern of response.

Muscle-pain patients reported a greater feeling of muscle tension at rest and during the stress period than did the control subjects. However, there were no significant differences in actual resting EMG activity or increased EMG activity from the laboratory stressor between the pain patients and the controls. Perhaps this feeling of greater muscle tension in pain patients may help us understand the etiology of muscle pain disorders. One possible explanation for the perception of increased muscle tension among our pain patients involves sensations arising from an increase in pressure from fluids within the myofascial sac surrounding the muscle tissues. Increased internal pressures have been previously documented in painful masseter muscles.[33] It is believed that this increased pressure is due to excess fluid in the interstitial areas of muscle tissue. Masticatory muscle–pain patients may similarly experience fluid accumulations within the tissues that give rise to the sensations of "muscle tension" in the absence of ongoing EMG activity. While at present this explanation is speculative, it certainly suggests a direction in which to explore in additional studies. It is known, for example, that blood flow is restricted in muscle tissues associated with myofascial pain.[34] The role of blood flow and interstitial fluid pressures needs to be more thoroughly explored in muscle pain patients as compared to matched controls.

Interest in the identification of the factors that distinguish TMD patients from normals has intensified in recent years. The results of our study contrast with several published studies and suggest that attention should be directed toward developing a large-scale, multisite evaluation study using standardized laboratory procedures. Our sample was limited in size and subjects were not matched according to weight. Moreover, we used only one laboratory stressor of a cognitive nature in our evaluation. Future studies should consider multiple stressors and should evaluate subjects in several body positions. Furthermore, the role of ambulatory EMG monitoring may become important in identifying to what extent EMG activity in the natural environment is a factor in the pathophysiology of masticatory muscle pain. While our results suggest that sympathetic overactivity may play an important role in the genesis of muscle pain, this hypothesis awaits experimental verification.

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Resumen

Comparación del funcionamiento psicológico y fisiológico entre pacientes con dolor muscular masticatorio y los pacientes de control

Este estudio exploró las diferencias psicológicas y fisiológicas entre los pacientes afectados por dolor muscular masticatorio y los controles acoplados de acuerdo a la edad y al sexo. Luego de completar varias pruebas psicológicas estandarizadas, los pacientes fueron sometidos a una evaluación en el laboratorio relacionada al perfil del stress para obtener medidas fisiológicas (electromiografía [EMG], ritmo cardiaco, presión sanguinea sistólica y diastólica) bajo condiciones de descanso, stress mental, y relajación. Los resultados indican que los pacientes afectados por el dolor reportaron una mayor ansiedad, especialmente síntomas cognoscitivos, y sensaciones de tensión muscular, en comparación a los controles apareados. Bajo stress, los pacientes adoloridos revelaron ritmos cardiacos y presiones sanguineas sistólicas mas pronunciadas que los controles. La actividad electromiográfica en las regiones maseteras no fue significativamente diferente entre el grupo afectado por dolor y el control. Se discuten los resultados en relación a los posibles mecanismos que pueden considerarse en relación a las diferencias observadas entre los pacientes afectados por dolor masticatorio y los sujetos normales.

Zusammenfassung

Vergleich zwischen Patienten mit Kaumuskel Schmerzen und passenden Kontrollpersonen hinsichtlich ihres psychologischen und physiologischen Funktionierens

Diese wissenschaftliche Untersuchung erforschte die psychologischen und physiologischen Unterschiede zwischen Patienten mit Kaumuskel Schmerzen und Kontrollen von passendem Alter und Geschlecht. Die Subjekte erledigten mehrere standardisierte psychologische Prüfungen. Diesen folgte eine Bewertung ihrer Stress-Profile, um ihre physiologischen Messungen (EMG, Puls, systolischen und diastolischen Blutdruck) in Zuständen von Ruhe, innerlichem Stress, und Erleichterung laboratorisch zu erhalten. Die Resultate zeigten an, dass Schmerz Patienten grössere Angst, besonders erkennbare Symptome, und Gefühle von muskulärer Spannung ausgedrückt haben als ihre passenden Kontrollpersonen. Unter Stress, Schmerz-Patienten zeigten schnelleren Puls und grösseren systolischen Blutdruck als ihre Kontrollen. EMG Aktivität in der Masseter Umgebung war nicht besonders differenziert zwischen der Schmerz-Gruppe und Kontroll-Gruppe. Die Resultate werden hinsichtlich ihrer wahrscheinlichen Mechanismen, welche für die beobachteten Unterschiede zwischen Patienten mit Kaumuskel Schmerzen und normalen Subjecten Rechnung tragen könnten, untersucht.