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Emotion regulation in adults with Klinefelter syndrome (47,XXY): Neurocognitive underpinnings and associations with mental health problems

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Abstract

Objectives: The aim of this study is to evaluate if language and executive functioning deficits in individuals with the 47,XXY chromosomal pattern contribute to emotion regulation problems and related symptoms of psychopathology.

Methods: A group of 26 adult men with 47,XXY completed measures of cognitive emotion regulation strategies, neurocognitive functioning, and symptoms of psychopathology.

Results: Atypical emotion regulation strategies were found in the XXY group, with increased expression of emotions (69%), avoiding (65%), distraction seeking (54%), and passive coping (54%). More difficulties in mental flexibility and attention regulation, and speeded responding were associated with more pronounced emotion expression (emotional outbursts). Emotion regulation problems were associated with symptoms of anxiety, depression, thought problems, and hostility.

Conclusion: This study has identified emotion regulation as a potential target for treatment and intervention, with a specific focus on executive functions in the management of emotions in individuals with 47,XXY.

KEYWORDS
47,XXY, cognition, coping, emotion regulation, Klinefelter syndrome, mental health, psychopathology, sex chromosome aneuploidy

1 | INTRODUCTION

Klinefelter syndrome (47,XXY), characterized by the presence of an extra X chromosome in males, is a genetic condition affecting approximately one in 650 boys and men. Even though it is among the most common chromosome aneuploidies, relatively little is known about the impact of the extra X chromosome on the development. So far, the majority of studies (75%) have focused on medical/somatic features, with only 25% of the studies investigating the cognitive and behavioral phenotype (Pieters, Kooper, van Kessel, Braat, & Smits, 2011). It is important to increase our knowledge in this domain, as a large-scale screening of hospital discharges in 860 adults with 47,XXY as compared with 86,000 men with the typical 46,XY pattern has shown that 47,XXY is associated with increased risk for psychopathology (Cederlof et al., 2014). Knowledge about these risks and the neuropsychological mechanisms driving this risk, are essential for improving diagnosis and treatment, especially since many cases (up to 75%) remain undiagnosed throughout life (Abramsky & Chapple, 1997). It has been suggested that this high rate of underdiagnosis may, in part, be due to low awareness of mental healthcare professionals, variable and nonspecific symptoms that do not necessarily fit the diagnostic classification systems, and difficulties men may experience in seeking for and organizing healthcare services (Herlihy & McLachlan, 2015). Quality of life in 47,XXY is on average lower in men with 47,XXY (Herlihy et al., 2011), and likely depends on the identification of mental health problems and the availability of interventions that is tailored to the mechanisms associated with the risk for psychopathology, calling for more research on these risks and mechanisms.

Although boys and men have been described in the literature as withdrawn, unassertive, or passive (Visootsak & Graham, 2009), many adolescents and men may also seek professional help for impulsive behaviors and emotional outbursts in stressful or frustrating situations. It is important to study this as it may help in explaining the reported lower quality of life, which includes academic and employment success (Herlihy et al., 2011). Of specific interest are the reported emotion regulation problems (Lee et al., 2015), as well as atypical emotion reactivity and emotion experience, as described below. Psychophysiological studies using skin conductance measures have revealed that 47,XXY adults may have a tendency to respond with increased arousal towards socioemotional cues (van Rijn, Barendse, van Goozen, & Swaab, 2014), and may have difficulties identifying and labeling experienced emotions (van Rijn, Barendse et al., 2014; van Rijn, Swaab, Aleman, & Kahn, 2006). This fits with reports of increased experiences of stress and anxiety during social interactions, both in adults and children with 47,XXY (van Rijn, Stockmann et al., 2014; van Rijn, Swaab, Aleman, & Kahn, 2008). Such deviations in the generation and processing of emotional responses fit with reports increased risk for compromised emotion regulation abilities in individuals with 47,XXY (Lee et al., 2015). Emotion regulation has been defined as the "processes that are responsible for the monitoring, evaluating, and modifying of emotional reactions in the service of achieving goals for well-being" (Thompson, 1994). Cognitive emotion regulation refers to the conscious cognitive way of handling the intake of emotionally arousing information (Thompson, 1994). Cognitive emotion regulation strategies are important for managing or regulating emotions or feelings, and to keep control over emotions and/or not getting overwhelmed by them, especially when arousal levels are high as in threatening or stressful events. Obviously, emotions have a functional role, and it is the reciprocal balance between lower order emotion systems that are automatic and reflexive, and higher order executive systems that allow for planned and strategic behaviors through top–down control, that is essential for adequate and adaptive behaviors. We hypothesized that these systems may function out of balance in a proportion of the men with 47,XXY.

Cognitive emotion regulation strategies have not yet been studied in 47,XXY, and the present study aims to provide in this. It is important to study this in 47,XXY, not only because emotion regulation problems may have a significant impact on daily life functioning, but also considering that emotion regulation problems are known to be associated with increased risk for mental healthcare problems. To illustrate, problems in the experience and regulation of emotions have been associated with social anxiety disorder, antisocial personality disorder, anxiety, depression, dysthymia, autism spectrum disorder, aggression, alexithymia, and psychosis spectrum disorders (Gross & Jazaieri, 2014).

In understanding the prevalence and nature of emotion regulation problems in 47,XXY, it is also important to focus on cognitive dysfunctions that may contribute to emotion regulation problems. Insights into such underlying neuropsychological mechanisms may help in understanding why emotion regulation problems may occur, and help us to identify potential targets for treatment or intervention. The cognitive phenotype of 47,XXY shows two domains of cognitive functioning with particular relevance to the management of emotions. The first is the domain of language abilities. Language is considered to provide an important tool in the regulation of emotions, as language allows labeling and categorizing of experienced emotions, communicating about emotions, and the implementation of emotion regulation strategies, such as reappraisal or distraction (Eisenberg, Sadovsky, & Spinrad, 2005; Fujiki, Brinton, & Clarke, 2002). As language abilities are compromised in a large proportion of individuals with 47,XXY (Boada, Janusz, Hutaff-Lee, & Tartaglia, 2009; Leggett, Jacobs, Nation, Scerif, & Bishop, 2010), this may put them at risk for difficulties in the management of emotions. The second is the domain of executive functions, which are essential in regulating and managing emotions, thoughts, and behaviors, according to environmental demands and constraints (Zelazo & Cunningham, 2007). Executive functions allow individuals to delay and reorient their behavior under circumstances that trigger automatic emotional responses, and to override the action tendency associated with the emotion, resulting in behaviors that are adaptive and socially acceptable (Zelazo & Cunningham, 2007). It is now increasingly recognized that a substantial proportion of individuals with 47,XXY have difficulties in executive functioning (EF; Kompus et al., 2011; Lee et al., 2011; van Rijn & Swaab, 2015; Samango-Sprouse et al., 2018; Skakkebaek et al., 2017), including impairments in attention regulation, inhibition, and mental flexibility, which may affect their ability to regulate emotions. The aim of this study is to evaluate if language and EF deficits in 47,XXY contribute to emotion regulation problems, and to assess to what degree emotion regulation problems are associated with risk for psychopathology.

2 | METHODS

2.1 | Participants

A group of 26 adults with 47,XXY, with a mean age of 40.8 (±11.1) years, participated in this study. Participants were recruited through research calls distributed by the Dutch Klinefelter support group in the Netherlands. The highest level of education was categorized using the International Standard Classification of Education (ISCED) 1997 system, developed by the United Nations Educational, Scientific and Cultural Organization, and implemented in the Netherlands (Luijkx & de Heus, 2008). The ISCED 1997 system rates educational level on a 6-point scale. The average score in the XXY group was 3.3 (standard deviation [SD] = 1.2). Scores ranged from 1 to 5, with 8% at Level 1, 23% at Level 2, 12% at Level 3, 42% at Level 4, and 15% at Level 5. As for the timing of diagnosis, 24 of the men had a postnatal genetic diagnosis versus four men with a prenatal diagnosis. With regard to the age of diagnosis, 22.7% were diagnosed in adolescence, typically because of delayed puberty, and 77.3% were diagnosed in adulthood, typically because of fertility problems. Almost all men (92.3%) were using testosterone supplements.

2.2 | Emotion regulation strategies

Coping strategies were measured using the Dutch coping questionnaire: The Utrechtse Coping Lijst (UCL), which has well-documented validity and reliability (Schreurs & van de Willige, 1988). Coping strategies refer to thoughts and actions that individuals can use to master, tolerate, reduce, or minimize emotions resulting from stressful events. The UCL consists of 49 items, with 7 subscales: *Active coping* (e.g., tackle a problem at once, label problems as a challenge, remain calm in challenging situations); *seeking distraction* (e.g., try to relax, going out, decrease the pressure by smoking, drinking, etc.); *avoiding* (e.g., let things take their course, wait to see how the wind blows); *seeking social support* (e.g., ask for help, share worries with others); *passive coping* (e.g., isolate oneself from others, worry about the past, take refuge in fantasies); *expressing emotions* (e.g., showing anger, let off steam); and *fostering*

reassuring thoughts (e.g., encourage oneself, telling oneself everything will be alright). Respondents are asked to score on a 4-point scale how often they made use of certain coping behaviors (seldom/never to very often). Higher scores indicate stronger characteristics. The UCL has been normed on a sample of 1,200 Dutch adults, with scores stratified according to gender and age. Cronbach's α for the UCL ranges from .55 to .86.

2.3 | Intellectual functioning and language

All participants completed the Dutch version of the Wechsler Adult Intelligence Scales-III (Wechsler, 2005). Full-scale IQ (FSIQ), verbal IQ (VIQ), and performance IQ (PIQ) were used as outcomes parameters for this study. The VIQ score was used as a measure of language abilities in the regression analyses.

2.4 | Cognitive abilities: EF

Inhibition and mental flexibility were measured using the shifting set task of the computerized Amsterdam Neuropsychological Tasks (ANT) program (De Sonneville, 1999), which has Dutch norm scores for children and adults with total sample sizes varying between 2,500 and 6,000 subjects, depending on the type of task. In the shifting set task, a colored square moves randomly to the right and to the left on a horizontal bar presented on the computer screen. Depending on the color of the square after the jump, the subjects should copy the movement or is required to "mirror" the movement, by clicking either the left or right of the mouse button. The task consists of three parts: In Part 1 (40 trials, green squares), the subject is required to copy the movements (fixed copy condition); in Part 2 (40 trials, red squares), only trials that call for "mirror" responses are presented (fixed mirror condition), requiring cognitive inhibition; and in Part 3 (80 trials, red and green squares), the square may change color upon each jump in a random fashion, which forces the subject to switch between response sets, requiring mental flexibility. Performance in Part 3 is registered separately for green squares (Part 3A: Variable copy condition) and red squares (Part 3B: Variable mirror condition). The outcome parameters used in this study were reaction times, with inhibition defined by the "fixed mirror (Part 2) minus fixed copy (Part 1)" conditions and mental flexibility defined by the "variable copy (Part 3A) minus fixed copy (Part 1)" conditions.

Speed of responding and attention regulation were measured using the baseline speed task of the ANT computerized test battery, which has Dutch norm scores for children and adults with total sample sizes varying between 2,500 and 6,000 subjects. The baseline speed task is a simple visual reaction time task, assessing intensity aspects of attention and alertness. On the screen, a (fixation) cross is continuously projected. This cross changes unexpectedly, and with random time intervals, into a square requiring the participant to press a mouse key as fast as possible, after which the square turns into a cross again, and so forth. There are 64 trials, which provide reaction times that reflect speed of responding, and fluctuations (*SD*'s) of reaction times that reflect basic regulation of attention.

To assess verbal EF in addition to the visual EF tests, a semantic verbal-fluency test was included as well. In the word-fluency test (Mulder, Dekker, & Dekker, 2006), participants are asked to produce as many words as possible from a category in 1 min. There were two categories (animals and professions) across which scores were averaged. The WFT has Dutch norm scores based on 310 individuals from the general population.

2.5 | Psychopathology

The Symptom Checklist-90-Revised (SCL-90-R) is a psychiatric self-report questionnaire (Arrindell & Ettema, 2003; Derogatis, 1994). It consists of 90 items scored on a 5-point scale from 0 (not at all) to 4 (extremely), indicating the rate of occurrence of the 90 symptoms in the last 7 days. Symptoms can be classified into several dimensions (Arrindell & Ettema, 2003). The Dutch version has a slightly different factor structure compared with the original version, and the following subscales were used for this study: Anxiety (10 items: Measuring symptoms that are

associated with manifest anxiety), Depression (16 items: Reflecting most of the typical symptoms of depressive syndromes according to current diagnostic criteria), Insufficiency in thinking and acting (9 items: This scale resembles the obsessive-compulsive scale of the original SCL-90), Interpersonal sensitivity and mistrust (18 items: A combination of interpersonal sensitivity and paranoid ideations and some items from the psychoticism dimension of the original version), and Hostility (6 items: Measuring thoughts, feelings, or actions characteristic of the negative affect state of anger). Furthermore, the total score of the SCL-90 can be used as a measure for general psychopathology. The SCL-90 is particularly useful for nonclinical patients who may be less symptomatic of specific disorders. The instrument has been validated with adult clinical as well as nonclinical groups. For this study, we used the Dutch norm scores based on 1,026 adults, with scores stratified according to gender. Internal consistencies of the scales have shown to be satisfactory in diverse populations (median Cronbach's α = .86; range 0.73–0.97).

2.6 | Statistical analyses

For all instruments, scores in the XXY group were compared with the Dutch norm scores. As our aim was to establish the degree of cognitive emotion regulation problems in the XXY group, one-sample Wilcoxon signed-rank tests were used to statistically test the XXY scores against the normative median score for each emotion regulation subscale of the UCL. As all other analyses were within-group tests, no other group comparisons were required. To evaluate if the use of emotion regulation strategies was dependent on the level of intellectual functioning within the XXY group, correlational analyses were performed with a threshold of p = .01 to correct for multiple comparisons. Linear regression analyses were performed with emotion regulation scores as the dependent variable, cognitive measures (inhibition, mental flexibility, verbal fluency, VIQ, attention regulation, speed of responding) as predictors in Box 1 (backward entry), and age as a predictor in Box 2 (enter entry). Additional linear regression analyses were performed with subscales of the SCL-90 as independent variables, and the emotion regulation strategies (showing significant group differences) as predictors (entered backward). The threshold for significance was set at p = .05.

3 | RESULTS

3.1 | Emotion regulation strategies

One-sample Wilcoxon signed-rank tests revealed that for several emotion regulation, subscales scores in the XXY group were significantly different from the normative sample. The XXY group had significantly higher scores for seeking distraction (Z = −3.29, p < .001), avoiding (Z = −3.15, p < .001), seeking social support (Z = 2.4, p = .01), passive coping (Z = −3.2, p = .001), and expression of emotion (Z = −3.39, p < .001). The scores for active coping (Z = −1.1, p = .24) and reassuring thoughts (Z = −0.25, p = .80) were not significantly different from the normative sample. The percentage of individuals with a low/very low score, average score, or high/very high score is presented in Figure 1.

3.2 | Correlation between IQ and emotion regulation strategies

Mean FSIQ was 92.6 (SD = 10.8), VIQ was 91.5 (SD = 11.6), and PIQ was 96.1 (SD = 10.9). All mean scores were within the normal range, although at the lower end. To evaluate if the use of emotion regulation strategies was dependent on the level of intellectual functioning in the XXY group, correlational analyses were performed. None of the emotion regulation strategies showed significant associations with FSIQ, PIQ, or VIQ (see Table 1 for results).
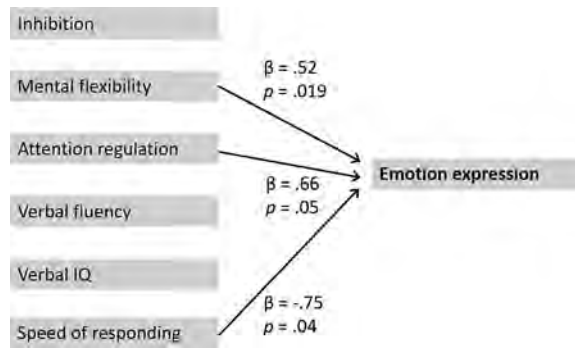
FIGURE 1 Percentage of individuals with XXY having "above average," "average," or "below average" use of various emotion regulation strategies. *Significantly different as compared with the normative sample

3.3 | Cognitive predictors of emotion regulation strategies

Group comparisons describing impairments in EF in this group of adults with 47,XXY have been published elsewhere (van Rijn, Aleman, De Sonneville, & Swaab, 2009; van Rijn, Bierman, Bruining, & Swaab, 2012). Linear regression analyses were performed with emotion regulation scores as the dependent variable, and cognitive measures (as well as age) as predictors. For emotion expression, a significant model was found, $F(4,20) = 2.8$, $p = .05$, which contained three significant predictors: Mental flexibility ($\beta = .52$, $t = 2.5$, $p = .019$), attention regulation ($\beta = .66$, $t = 2.0$, $p = .05$), and speed of responding ($\beta = -.75$, $t = -2.1$, $p = .04$). More expression of emotion was predicted by more difficulties in mental flexibility and attention regulation, and faster speed of responding (see Figure 2). For other emotion regulation strategies, no significant models were found.

3.4 | Emotion regulation in relation to psychopathology

To assess if emotion regulation strategies (those showing differences from the normative sample) were related to psychopathology in men with 47,XXY, linear regression analyses were performed. SCL-90 total score was significantly predicted by the emotion regulation strategies avoidance and passive reacting. Looking at specific

TABLE 1 Correlations between IQ scores and emotion regulation strategies

	FSIQ	PIQ	VIQ
Active coping	$r = .18$ $p = .36$	$r = .06$ $p = .74$	$r = .31$ $p = .10$
Seeking distraction	$r = .13$ $p = .50$	$r = .10$ $p = .59$	$r = .15$ $p = .43$
Avoiding	$r = .13$ $p = .50$	$r = .35$ $p = .06$	$r = -.04$ $p = .85$
Seeking social support	$r = .23$ $p = .24$	$r = .14$ $p = .47$	$r = .22$ $p = .26$
Passive coping	$r = .15$ $p = .44$	$r = .002$ $p = .99$	$r = .17$ $p = .38$
Expression of emotions	$r = -.05$ $p = .81$	$r = .07$ $p = .73$	$r = -.03$ $p = .86$
Reassuring thoughts	$r = -.08$ $p = .67$	$r = -.08$ $p = .69$	$r = -.06$ $p = .77$

Note: Significantly different as compared with the normative sample.

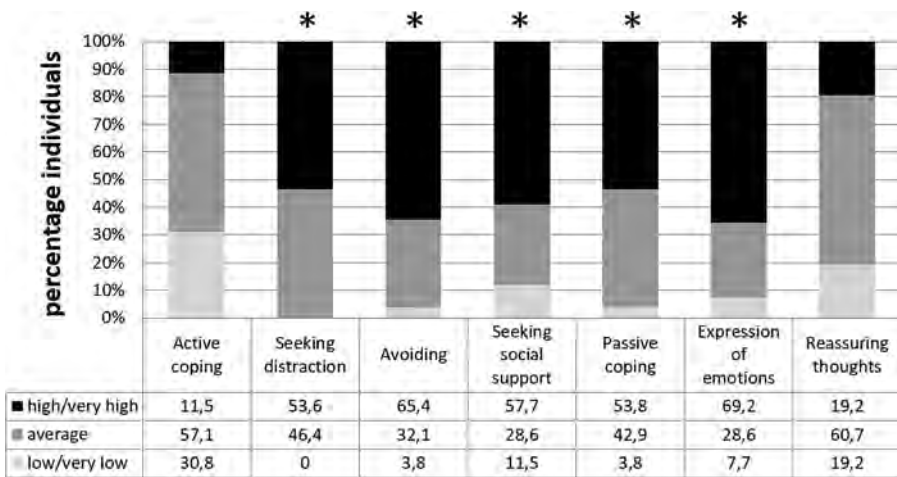|	Active coping	Seeking distraction	Avoiding	Seeking social support	Passive coping	Expression of emotions	Reassuring thoughts
■ high/very high	11,5	53,6	65,4	57,7	53,8	69,2	19,2
▨ average	57,1	46,4	32,1	28,6	42,9	28,6	60,7
▨ low/very low	30,8	0	3,8	11,5	3,8	7,7	19,2

FIGURE 2 Cognitive abilities that significantly predict the emotion regulation strategy "emotion expression" in men with XXY

SCL-90 subscales, passive coping was a significant predictor for the majority of subscales. Avoidance was a significant predictor for depression specifically. The results are presented in Table 2.

4 | DISCUSSION AND CONCLUSION

The findings of this study suggest that emotion regulation may be atypical in a proportion of adults with 47,XXY, which calls for a better understanding of the processing and management of emotions in the 47,XXY population. The most prominent emotion regulation strategy in the XXY group in this study was "expression of emotions," which was significantly increased with scores in the above average range in 69% of the men. This suggests that when arousal levels increase in response to stress, a large proportion of men with XXY have difficulties regulating these emotions resulting in emotional outbursts; showing frustration/anger or letting off steam. This was followed by significantly more "avoiding" (e.g., let things take their course), with 65% of the men in the above-average range,

TABLE 2 Overview of regression models in which emotion regulation strategies were significant predictors of psychopathology (SCL-90) in men with XXY

SCL-90	Model statistics	Explained variance	Predictors in model
Total score	$F(2,23) = 11.2$, $p < .001$	49%	Passive coping: $\beta = .68$, $t = 4.5$, $p < .001$) Avoidance: $\beta = .33$, $t = 2.1$, $p = .03$
Anxiety	$F(1,24) = 19.4$, $p < .001$	45%	Passive coping: $\beta = .67$, $t = 4.4$, $p < .001$
Depression	$F(2,23) = 19.0$, $p < .001$	62%	Passive coping: $\beta = .80$, $t = 6.1$, $p < .001$) Avoidance: $\beta = .23$, $t = 1.8$, $p = .08$
Insufficiency of thinking/ acting	$F(1,24) = 15.4$, $p = .001$	39%	Passive coping: $\beta = .62$, $t = 3.9$, $p = .001$
Distrust and interpersonal sensitivity	Not significant	–	–
Hostility	$F(1,24) = 17.8$, $p < .001$	43%	Passive coping: $\beta = .65$, $t = 4.3$, $p < .001$

Abbreviation: SCL-90, Symptom Checklist-90.

significantly more "seeking distraction" (e.g., going out, decrease the pressure by smoking, drinking etc.) and significantly more "passive coping" (e.g., isolate oneself from others, worry about the past), both of which were in the above-average range in 54% of the men. Interestingly, "seeking social support" was also significantly increased, with 58% of the men in the above-average range. This suggests that many men with XXY also tend to ask for help or share worries with others in response to stress, which could be positively implemented in the treatment of mental healthcare problems.

Emotion regulation abilities were independent of age in this adult XXY group ranging in age from 19 to 65 years. In terms of the neurocognitive functions associated with emotion regulation, FSIQ (ranging from 71 to 117), PIQ (ranging from 75 to 116), and VIQ (ranging from 71 to 121) were no significant predictors of regulation strategies, suggesting that the type and use of emotion regulation strategies were independent of intellectual abilities. The finding that VIQ was not associated with emotion regulation suggests that the type of emotion regulation difficulties were not necessarily resulting from problems in language expression or language understanding.

This study did identify executive functions as predictors of emotion regulation abilities, specifically in relation to increased emotion expression. More difficulties in mental flexibility and attention regulation, as well as speeding responding were associated with more pronounced emotion expression, that is, emotional outbursts. Executive functions are essential in regulating and managing emotions, by allowing individuals to delay and reorient their behavior under circumstances that trigger automatic emotional responses, and to override the action tendencies associated with the emotion, resulting in behaviors that are adaptive and socially acceptable. The present study suggests that impairments in executive functions that have been reported in earlier studies may limit the ability of men with 47,XXY to regulate their emotions and generate adaptive socioemotional behavior. Although speculatively, based on the wide literature on the importance of the frontal lobes for self-regulation, emotional reactivity, and executive control (Heatherton & Wagner, 2011; Stuss, 2011), one hypothesis may be that executive dysfunctions and related emotion regulation problems may be driven by abnormal structure and function of the frontal lobes in XXY, which is also supported by neuroimaging findings in XXY (Lenroot, Lee, & Giedd, 2009).

This study also suggests that emotion regulations problems in XXY may be associated with various mental health problems. An increased tendency for passive coping (e.g., isolating oneself from others, worrying about the past, taking refuge in fantasies) was associated with a wide range of symptoms of psychopathology, including symptoms of anxiety, depression, thought problems, and hostility. In addition, the strategy "avoiding" was specifically linked to depressive symptoms. These findings illustrate the importance of focusing on emotion regulation in improving daily life functioning and quality of life of adults with 47,XXY. The study has identified emotion regulation abilities as possibly relevant targets in treatment and intervention, with the potential to reduce the risk for more serious psychopathology and increase adaptive functioning within society, including functioning in academic and professional settings. Insight in EF as an underlying neurocognitive mechanism of emotion regulation may help us in providing more targeted treatment, focused on the mechanisms driving emotion regulation difficulties. Identifying the underlying mechanisms of mental health problems, and the interplay between such determinants may be a useful approach, as shown in other studies on XXY as well (Skakkebæk et al., 2018).

For clinicians, both emotion regulation and EF should be the focus of clinical assessment and treatment. Support should not be limited to training or intervention programs, but also include psychoeducation: Insight in own strengths and weaknesses may help to better understand, accept, and cope with challenges, and may contribute to making choices in daily life that better match the needs and limitations of an individual. To meet these aims, it is important to screen for executive dysfunction when men with 47,XXY present with emotional outbursts and other manifestations of loss of control over emotions. Our recommendations for clinical screening of problems in EF include: (a) The use of computerized neuropsychological testing rather than solely relying on questionnaires for EF, (b) assessment of specific/isolated executive functions to identify the type of EF deficit (if present), (c) relying on sensitive measures of EF to be able to also pick up on more subtle deficits, and not only the more severe cases, and (d) screening for EF as a part of a more comprehensive neuropsychological assessment.

This study had some limitations. Self-report measures were used, which always rely on subjective evaluation of participants. Nonetheless, all had good psychometric properties. Also, the sample size was rather small; we hope that current findings encourage future studies of emotion regulation using larger sample sizes. Furthermore, the majority of men was diagnosed postnatally, which may have affected the representativeness of the findings for the total population. However, it is important to emphasize that the sample was recruited for research purposes, and not for clinical care. Even though this study involved some degree of bias, which is typical for the majority of research on 47,XXY with postnatal cohorts likely overestimating severity of the phenotype (due to preselection of more severe cases) and prenatal cohorts likely underestimating severity (due to higher socioeconomic status and effects of early support), findings of the current study are valuable as emotion regulation problems and executive dysfunction are important diagnostic considerations and recognition by professionals is essential in improving clinical care. Finally, due to the design of this study, we were not able to address the degree to which atypical emotion regulation and EF is related to testosterone abnormalities in men with 47,XXY. The effect of supplementation requires a randomized controlled trial, assessing changes in EF, and emotion regulation before and after starting supplementation.

The results from this study call for further investigation of emotion regulation, and the contribution of executive dysfunction, in children and adolescents with 47,XXY. Previous studies have shown that problems in EF may present already in childhood in a proportion of the individuals with 47,XXY (van Rijn & Swaab, 2015). These children may be vulnerable to deficient emotion regulation development and may be at increased risk for mental health problems later in life. Early monitoring allows for the implementation of early preventive strategies, which has the potential to influence child development towards more optimal outcomes (Guralnick, 2011).

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REFERENCES

Abramsky, L., & Chapple, J. (1997). 47,XXY (Klinefelter syndrome) and 47,XYY: Estimated rates of and indication for postnatal diagnosis with implications for prenatal counselling. *Prenatal Diagnosis*, *17*(4), 363–368. https://doi.org/10.1002/(sici)1097-0223(199704)17:4<363::aid-pd79>3.0.co;2-o

Arrindell, W. A., & Ettema, J. H. M. (2003). *Symptom checklist (SCL-90): Handleiding bij multidimensionale psychopathologie-indicator*. Amsterdam, The Netherlands: Pearson Assessment and Information B.V.

Boada, R., Janusz, J., Hutaff-Lee, C., & Tartaglia, N. (2009). The cognitive phenotype in Klinefelter syndrome: A review of the literature including genetic and hormonal factors. *Developmental Disabilities Research Reviews*, *15*(4), 284–294.

Cederlöf, M., Ohlsson Gotby, A., Larsson, H., Serlachius, E., Boman, M., Långström, N., ... Lichtenstein, P. (2014). Klinefelter syndrome and risk of psychosis, autism and ADHD. *Journal of Psychiatric Research*, *48*(1), 128–130. https://doi.org/10.1016/j.jpsychires.2013.10.001

Derogatis, L. R. (1994). *SCL-90-R: Administration, scoring and procedures manual* (3rd ed.). Minneapolis, MN: Nation Computer Systems.

Eisenberg, N., Sadovsky, A., & Spinrad, T. L. (2005). Associations of emotion-related regulation with language skills, emotion knowledge, and academic outcomes. *New Directions for Child and Adolescent Development*, *2005*, 109–118.

Fujiki, M., Brinton, B., & Clarke, D. (2002). Emotion regulation in children with specific language impairment. *Language, Speech, and Hearing Services in Schools*, *33*(2), 102–111. https://doi.org/10.1044/0161-1461

Gross, J. J., & Jazaieri, H. (2014). Emotion, emotion regulation, and psychopathology: An affective science perspective. *Clinical Psychological Science*, *2*(4), 387–401. https://doi.org/10.1177/2167702614536164

Guralnick, M. J. (2011). Why early intervention works: A systems perspective. *Infants & Young Children*, *24*(1), 6–28. https://doi.org/10.1097/IYC.0b013e3182002cfe

Heatherton, T. F., & Wagner, D. D. (2011). Cognitive neuroscience of self-regulation failure. *Trends in Cognitive Sciences*, *15*(3), 132–139.

Herlihy, A. S., & McLachlan, R. I. (2015). Screening for Klinefelter syndrome. *Current Opinion in Endocrinology, Diabetes, and Obesity*, *22*(3), 224–229. https://doi.org/10.1097/med.0000000000000154

Herlihy, A. S., McLachlan, R. I., Gillam, L., Cock, M. L., Collins, V., & Halliday, J. L. (2011). The psychosocial impact of Klinefelter syndrome and factors influencing quality of life. *Genetics in Medicine*, *13*(7), 632–642. https://doi.org/10.1097/GIM.0b013e3182136d19

Kompus, K., Westerhausen, R., Nilsson, L. G., Hugdahl, K., Jongstra, S., Berglund, A., … Savic, I. (2011). Deficits in inhibitory executive functions in Klinefelter (47, XXY) syndrome. *Psychiatry Research*, *189*(1), 135–140. https://doi.org/10.1016/j.psychres.2011.02.028

Lee, N. R., Anand, P., Will, E., Adeyemi, E. I., Clasen, L. S., Blumenthal, J. D., … Edgin, J. O. (2015). Everyday executive functions in Down syndrome from early childhood to young adulthood: Evidence for both unique and shared characteristics compared to youth with sex chromosome trisomy (XXX and XXY). *Frontiers in Behavioral Neuroscience*, *9*, 264. https://doi.org/10.3389/fnbeh.2015.00264

Lee, N. R., Wallace, G. L., Clasen, L. S., Lenroot, R. K., Blumenthal, J. D., White, S. L., … Giedd, J. N. (2011). Executive function in young males with Klinefelter (XXY) syndrome with and without comorbid attention-deficit/hyperactivity disorder. *Journal of the International Neuropsychological Society*, *17*(3), 522–530. https://doi.org/10.1017/s1355617711000312

Leggett, V., Jacobs, P., Nation, K., Scerif, G., & Bishop, D. V. M. (2010). Neurocognitive outcomes of individuals with a sex chromosome trisomy: XXX, XYY, or XXY: A systematic review. *Developmental Medicine and Child Neurology*, *52*(2), 119–129. https://doi.org/10.1111/j.1469-8749.2009.03545.x

Lenroot, R. K., Lee, N. R., & Giedd, J. N. (2009). Effects of sex chromosome aneuploidies on brain development: Evidence from neuroimaging studies. *Developmental Disabilities Research Reviews*, *15*(4), 318–327.

Luijkx, R., & de Heus, M. (2008). The educational system of the Netherlands. In S. L. Schneider (Ed.), *The International Standard Classification of Education (ISCED-97). An evaluation of content and criterion validity for 15 European countries* (pp. 47–75). Mannheim, Germany: Mannheimer Zentrum für Europäische Sozialforschung.

Mulder, J. L., Dekker, P. H., & Dekker, R. (2006). *Word-Fluency Test: Manual [Woord-Fluency Test: Handleiding]*. Leiden, The Netherlands: PITS BV.

Pieters, J. J. P. M., Kooper, A. J. A., van Kessel, A. G., Braat, D. D. M., & Smits, A. P. T. (2011). Incidental prenatal diagnosis of sex chromosome aneuploidies: Health, behavior, and fertility. *ISRN Obstetrics and Gynecology*, *2011*, 807106. https://doi.org/10.5402/2011/807106

van Rijn, S., Aleman, A., De Sonneville, L., & Swaab, H. (2009). Cognitive mechanisms underlying disorganization of thought in a genetic syndrome (47,XXY). *Schizophrenia Research*, *112*(1–3), 91–98. https://doi.org/10.1016/j.schres.2009.04.017

van Rijn, S., Barendse, M., van Goozen, S., & Swaab, H. (2014). Social attention, affective arousal and empathy in men with Klinefelter syndrome (47,XXY): Evidence from eyetracking and skin conductance. *PLoS One*, *9*(1), e84721. https://doi.org/10.1371/journal.pone.0084721

van Rijn, S., Bierman, M., Bruining, H., & Swaab, H. (2012). Vulnerability for autism traits in boys and men with an extra X chromosome (47,XXY): The mediating role of cognitive flexibility. *Journal of Psychiatric Research*, *46*(10), 1300–1306. https://doi.org/10.1016/j.jpsychires.2012.06.004

van Rijn, S., Stockmann, L., Borghgraef, M., Bruining, H., van Ravenswaaij-Arts, C., Govaerts, L., … Swaab, H. (2014). The social behavioral phenotype in boys and girls with an extra X chromosome (Klinefelter syndrome and Trisomy X): A comparison with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *44*(2), 310–320. https://doi.org/10.1007/s10803-013-1860-5

van Rijn, S., & Swaab, H. (2015). Executive dysfunction and the relation with behavioral problems in children with 47,XXY and 47,XXX. *Genes, Brain, and Behavior*, *14*(2), 200–208. https://doi.org/10.1111/gbb.12203

van Rijn, S., Swaab, H., Aleman, A., & Kahn, R. S. (2006). X chromosomal effects on social cognitive processing and emotion regulation: A study with Klinefelter men (47,XXY). *Schizophrenia Research*, *84*(2–3), 194–203. https://doi.org/10.1016/j.schres.2006.02.020

van Rijn, S., Swaab, H., Aleman, A., & Kahn, R. S. (2008). Social behavior and autism traits in a sex chromosomal disorder: Klinefelter (47XXY) syndrome. *Journal of Autism and Developmental Disorders*, *38*(9), 1634–1641. https://doi.org/10.1007/s10803-008-0542-1

Samango-Sprouse, C., Stapleton, E., Chea, S., Lawson, P., Sadeghin, T., Cappello, C., … van Rijn, S. (2018). International investigation of neurocognitive and behavioral phenotype in 47,XXY (Klinefelter syndrome): Predicting individual differences. *American Journal of Medical Genetics, Part A*, *176*(4), 877–885. https://doi.org/10.1002/ajmg.a.38621

Schreurs, P., & van de Willige, G. (1988). *Handling problems and occurrences. The Utrecht coping questionnaire (in Dutch)*. Lisse, The Netherlands: Swets & Zeitlinger.

Skakkebaek, A., Moore, P. J., Pedersen, A. D., Bojesen, A., Kristensen, M. K., Fedder, J., … Gravholt, C. H. (2017). The role of genes, intelligence, personality, and social engagement in cognitive performance in Klinefelter syndrome. *Brain and Behavior*, *7*(3), e00645. https://doi.org/10.1002/brb3.645

Skakkebaek, A., Moore, P. J., Pedersen, A. D., Bojesen, A., Kristensen, M. K., Fedder, J., … Gravholt, C. H. (2018). Anxiety and depression in Klinefelter syndrome: The impact of personality and social engagement. *PLoS One*, *13*(11), e0206932. https://doi.org/10.1371/journal.pone.0206932

De Sonneville, L. M. J. (1999). Amsterdam neuropsychological tasks: A computer-aided assessment program. In Den Brinker, B. P. L. M., Beek, P. J., Brand, A. N., Maarse, S. J., & Mulder, L. J. M. (Eds.), *Cognitive ergonomics, clinical assessment and computer-assisted learning: Computers in psychology* (6). Lisse, The Netherlands: Swets & Zeitlinger.

Stuss, D. T. (2011). Functions of the frontal lobes: Relation to executive functions. *Journal of the International Neuropsychological Society*, *17*(05), 759–765. https://doi.org/10.1017/S1355617711000695

Thompson, R. A. (1994). Emotion regulation: A theme in search of definition. *Monographs of the Society for Research in Child Development*, *59*(2–3), 25–52.

Visootsak, J., & Graham, J. M. (2009). Social function in multiple X and Y chromosome disorders: XXY, XYY, XXYY, XXXY. *Developmental Disabilities Research Reviews*, *15*(4), 328–332.

Wechsler, D. (2005). *WAIS-III NL. Wechsler adult intelligence scale WAIS-III (Dutch version. Manual).* (3rd ed.). Amsterdam, The Netherlands: Harcourt Test Publishers.

Zelazo, P. D., & Cunningham, W. A. (2007). Executive function: Mechanisms underlying emotion regulation. In Gross, J. (Ed.), *Handbook of emotion regulation* (pp. 135–158). New York, NY: Guilford.